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ASTREPHA (TRYPETYDAE, DIPTERA) FRUIT FLIES IN PUERTO RICO

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Two species of fruit flies of the genus *Anastrepha* occur in the land of Puerto Rico. In this region, they can be conveniently differentiated on the basis of the host selection, that is, the fruits in which the maggots are found, although in the case of two of the host fruits, both species may be found together. The two species can unquestionably be differentiated in the egg and adult stages. In the larval stage, the one character used to distinguish them seems to be constant. One is described as a distinct new species: *unipuncta*. The other, although differing greatly in host fruits from the species *fraterculus* as reported from some localities in South America, is here considered as a variety of that species: *mombinpraeoptans* because of its preference for the hog plum, (*Spondias mombin* L.). The lack of more data from South America does not seem to justify greater differentiation at present.

What has previously been called the West Indian fruit fly, *Anastrepha fraterculus*, was described by Wiedemann (**10**) in 1830 from Brazilian specimen and was first reported from Puerto Rico by Sundlach (**4**) in 1887 as *Acrotoxa fraterculus* and *Trypeta fraterculus* Wied., in synonymy as determined by Roeder. Up to recently was considered the only species of *Anastrepha* on the Island.

In 1911, after the Puerto Rico Experiment Station at Mayagüez had introduced some of the selected East Indian varieties of mangoes it was noticed that some, especially the Cambodiana, were attacked by fruit flies, and in that same year, Tower (**9**) published an account of the life history of the insect under the name of *Anastrepha sidusa* Walker, as determined by W. R. Walton.

In 1912, Dr. Hooker (**5**) also of the Puerto Rico Station reported that a comparison made by Dr. L. O. Howard with the type of *A. sidusa* in the British Museum showed the fruit fly from Puerto Rico (it is not possible to tell which of the two) to be a different species, possibly undescribed. In the same report, however, it is added that

Prof. Bezzi identified specimens as *A. fraterculus* and that Mr. Knab was inclined also to consider them as belonging to that species.

In Dr. Wolcott's check list of the insects of Puerto Rico (11) published in 1923, *A. fraterculus* is the only species recorded, and *A. acidusa* is given as a synonym. The host plants of the two species are given as those of the single species recognized at the time.

In 1925, at a hearing (7) held in Washington, D. C., to consider prohibiting or restricting the entrance of citrus fruits from Puerto Rico into the United States due to the presence of *A. fraterculus*, Dr. C. L. Marlatt expressed the opinion that although *A. fraterculus* did not infest citrus fruits in Puerto Rico, *Anastrepha* larvae had been found on one occasion in citrus from the Isle of Pines and furthermore stated that:

"In our examination of citrus fruits from the West Indies and Mexico, Central America, etc., we find that these native fruit flies which occur throughout all that region do not attack citrus. It is not at all impossible that there may be a rare case of a maggot of these other fruit flies coming in citrus fruit. The insect may lay eggs under some abnormal conditions in citrus fruit and there is a possibility of course that infestation may result."

Since this hearing, the exportation of citrus fruits from Puerto Rico into the United States has continued uninterruptedly, the shipments being accompanied by permits issued by Inspectors of the Bureau of Plant Quarantine stationed on the Island. The permits are based on inspections made throughout the year in the groves and again in the packing houses before shipment. The inspections are most carefully conducted during the spring and summer and since 1931, with special care in the localities where infestations might be considered more likely to occur. As stated by Dr. G. G. Becker in the report on his trip of inspection to Puerto Rico, May 28 to June 13, 1931:

"A much greater fruit-fly risk is assumed in shipments of Cuban and Isle of Pines citrus than is assumed with Puerto Rican citrus because of the fact that fruit from the former Islands is given only a cursory examination on arrival."

In April, 1926, Mr. José Luciano of the Insular Quarantine Service found one fruit-fly larva in a native sweet orange (grown most likely in the western part of the Island) which was identified by Mr. C. T. Greene as *Anastrepha* sp. In the spring and summer of 1931 some infested grapefruit, sour oranges and one native sweet orange were found in the western part of the Island and a few infested Valencia oranges in two trees in a large commercial grove in the northern

part. In April 15, 1932, a few infested grapefruits and some sour oranges (very remarkably in the same grove and practically on the same date as the previous year), were again found in the west and a few infested sour oranges were also found in one locality in the south. Those infestations, as shown by careful surveys conducted by inspectors of the Bureau of Plant Quarantine and the Insular Quarantine Service in cooperation, have all been localized, of short duration and involving only an infinitesimal number of fruits compared with the total crop of the Island. Nothing can be added at present to the statements made by Dr. Marlatt to explain why those infestations take place. They do not occur when the flies are more abundant and neither do they seem to be caused simply by a lack or scarcity of their ordinary host fruits. They might possibly be due to a special activity of some of the flies in the spring and summer, or to a certain tendency of some individuals. Whatever the cause, and even though the host plants of the insect occur in the neighborhood of practically all the citrus groves in the Island without infestation taking place, the elimination of those host plants would eliminate the source of flies in the vicinity of the groves and therefore also the danger of infestation. Picking the fruit early would also reduce the danger since the infestations have been found in the spring and at the beginning of summer. The fly that has been reared from citrus fruits in Puerto Rico is *not* the one that breeds in mango, "jobo", and "ciruela" but another distinct species which breeds commonly in guava, rose apple, to some extent in tropical almond and less commonly in custard apple, star apple, zapodilla, beach plum and kunquat.

So much confusion exists as to what are the characters of *Anastrepha fraterculus* Wied., that it would seem desirable to describe what has been considered to be that species in Puerto Rico as new. But due to lack of sufficient reared material and data on the immature stages from a large number of localities throughout its wide range in the West Indies, Central and South America, for the present, the insect as found in Puerto Rico is here redescribed as a variety within the species *fraterculus.* Several such varieties may eventually be established and some may prove to be distinct species. The creation of varietal names will facilitate the study of the genus *Anastrepha* and particularly the species *fraterculus.* It may be useful also in connection with quarantine regulations. A long list of plants has been reported infested by *A. fraterculus,* but in some localities where *A. fraterculus* is reported to occur, some of those plants are not infested. Manifestedly, one locality should not be put under

quarantine regulations on the basis of the plants the insect attacks in another. The reason why some plants are infested in one locality and not in another may most readily be explained perhaps, by the existence of varieties within the species *fraterculus*. It is possible also that in some localities, plants reported infested by *A. fraterculus* may have been infested, as in Puerto Rico, by some other closely related species heretofore confused with it.

On this basis it would appear desirable to retain the common name of West Indian fruit fly, restricting it to the mango and jobo infesting variety: *mombinpræoptans*, which does not attack citrus in Puerto Rico. This variety is probably found in other West Indian islands besides Puerto Rico, and presumably also in tropical Central and South America. For the variety (if we may consider it as such) of *A. fraterculus* which attacks citrus and subtropical fruits in Brazil, Argentina and other South American countries, the common name of South American fruit fly as used by Essig (**2**) would be appropriate. Essig, when using that term in his book, was not considering varieties.

In describing the adult, the three bands on the wings (Fig. 60) are given names. The basal band extends from the base of the wing along the costal border to the end of the apical cell. The S-shaped band is clearly marked from the tip of the wing along the anterior margin to about the middle, thence bending over the radio-medial cross-vein it reaches the tip of the anal cell diffusing over it towards the base of the wing. The two arms of the inverted V-band rest on the posterior margin. Because there is no connection between them, the basal and the S-shaped bands stand out very clearly in figures 2 and 60. In figure 3 (*A. fraterculus* from Argentine), there being no connection between the S-band and the inverted V-band, the shape of the latter is quite striking. In describing wings such as shown in figures 2 and 3, the three bands immediately catch the eye. In figure 1, however, because of the connections, the three-banded effect is somewhat lost. Although *A. fraterculus* in Argentine is not discussed in detail in this paper, an illustration of the wing has been introduced for comparison.

In obtaining the eggs of the two species, it has been found convenient to take advantage of the fact that the females when kept for a time in cages without fruits in which to oviposit, seem to be in such a hurry when suitable fruits are made available, that they deposit the first eggs on the surface of the fruits as they run over them trailing the ovipositor. The normal shape and size of the eggs can be more easily observed in such than in eggs dissected out of

the flies or out of the fruits. In the variety *mombinpraeoptans* the tips of the eggs protruding out of the cuticle of the fruits makes the search for them a simple operation, but unless the spot where the females insert the ovipositor in fruits in cages is marked, it is quite difficult to locate those of *A. unipuncta*, which are deposited entirely under the cuticle.

Wiedemann's Description of **A. fraterculus**

"Flavus; alis dimidio basilari costae, plaga S formi, fascia dimidia lineaque apicis obliqua flavis. Yellow, wing with basal half of rib yellow, "S" formed mark, half a hyphen and line at apex.

"Length 2⅔ lines. From Brazil.

"This species is much similar to *D. parallelus*, only it is much smaller, the costal stripe and the band and the line, which correspond to the third stripe of that one, are different. Antennae medium length, bristle not plumose. Color very pale rust yellowish; face the same, frons somewhat deeper yellow. Entire back (thorax) of a pale yellow in between acorn-brown to 'Izabell yellow',—this perhaps lost of its purity through smears with arsenic solution. Abdomen fuller yellow, sides of thorax and legs leather-yellow. Abdomen incisions (posterior edge of segments whitish. Bristles and hair of head and body black. Base of wing from the costa to the third longitudinal vein deep yellow, in the radial cell lighter. From the inner hind margin, near the base of the wing, an oblique "S" mark runs over the middle cross-vein with its first bend reaching the costa, (whereby there is left a triangular hyaline space between it and the basal stripe), then with a sharp bending along the outer wing margin to below the end of the third longitudinal vein. From the hind edge of the wing there is a hyphen (band) spreading over the ordinary cross-vein and reaching to about the middle of the wing width; from the hind margin of the wing apex a tapering line extends obliquely and reaches over the end of the band, but in no way connected with the same. Band and line are slightly brown. In my collection."

Anastrepha fraterculus Wied., var. **mombinpraeoptans,** new variety.

The adult: Maximum size, male 7 mm., female (Fig. 4) with ovipositor, 8 mm., ovipositor, 1.8 mm. Wing expanse, 14 to 15 mm.(1) Head yellow, face light lemon yellow, front a grayish yellow amber. Compound eyes metallic irridescent. An almost black bloch between the simple eyes. Antennae with slight reddish tinge, arista chestnut. Proboscis golden yellow, palpi with very slight reddish tinge. Thorax dorsally reddish brown (2) with dark chestnut or blackish pile (3);

(1) In Wiedemann's description the size is given as 2⅔ lines. In Pierce's manual it is 12 mm., exclusive of the ovipositor with a wing expanse slightly over 25 mm. In Argentina according to Rust (8) average sizes are for the male 7 to 8 mm., with a wing expanse of 15 to 16 mm., and for the female 10 to 11 mm., with the ovipositor, ovipositor 2 mm. and wing expanse 18 to 20 mm.

(2) According to Wiedemann: "the entire back (thorax) is of a pale yellow in between acorn-brown and Isabell-yellow, this perhaps lost of its purity through smears with arsenic solution."

median mesoscutal vitta sulphur yellow with whitish pile(3), linear from collar expanding posteriorly into a cuneiform shape not reaching scutellum (Fig. 37); scutellum and lateral mesoscutal vitta sulphur yellow with scanty blackish pile. Metanotum a reddish amber with or without two markings which may be light or dark, shaped as spots or larger blotches Side of thorax dull yellow, pleural vitta enamelled sulphur yellow. An almost black rounded spot behind the wing base(4). The usual bristles all black. Abdomen amber with blackish pile and black bristles, posterior edges of segments usually showing as three lighter transverse bands. Ovipositor reddish amber, darker than abdomen, dorsally with an almost black spot near the tip. Two rounded, almost black spots on the membrane at the base of the ovopositor(4).

Legs lighter yellow than body, tibiae and tarsi, slightly tinged with reddish.

Wings (Fig. 1) hyaline, iridescent, markings in the shape of three brownish orange bands overlaid in part with a smoky brown which in places is blackish. The borders of the bands darker in places. Occasional vacuoles or lightly pigmented areas in the bands. Basal band brownish orange from the base of the wing to apical cell. Apical cell darker. S-shaped band dark smoky from tip of wing along anterior margin to about the middle, thence dark brownish orange over the radiomedial cross-vein and lighter brownish orange over it into cell 1st M_2. On cell Cu_1 there are usually two dark spots, sometimes coalescing, one of which is on the tip of the anal cell(5). The basal and the S bands are connected at a point near the r-m cross-vein thus leaving a triangular or notch shaped hyaline area between them with its base on the anterior margin and the apex pointing towards the posterior margin of the wing. Inverted V band with its arms resting on the posterior margin, the vertex connecting with the S band, the connection usually strong(6), the vertex is brownish orange, the arms smoky. Very exceptionally (Fig. 55) the arms of the inverted V band may be disconnected as described by Wiedemann. In one specimen the S band was found to be cut in two at the middle, (Fig. 56). Figures 43 to 56 show some only of the more striking variations that occur in the *mombinpraeoptans* variety.

Described from 3,000 freshly killed specimens reared by the writer from the different fruits in which the insect breeds in Puerto Rico during the years 1927 to 1933 from many localities both in the costal plain and the higher elevations. Dried specimens in the collections of the Insular and Puerto Rico Experiment Stations and in the National Museum in Washington, D. C., some of them collected as far back as 1913 and identified as *A. fraterculus* have also been examined. Dried specimens are brownish with the vittae whitish.

Type.—A single female; (P. R. Ac. No. 44–33), March 20, 1933, Río Piedras, Puerto Rico; reared by F. Seín, Jr., from *Spondias mombin* L. In the U. S. National Museum, Washington, D. C.

Paratypes.—Four female specimens; (P. R. Ac. No. 44–33), March 20, 1933,

(3) In Wiedemann's description the bristles and hairs of head and body are black, but according to Loew (6) the pile on Wiedemann's type was light chestnut or yellowish. Dr. C. H. Curran has informed the writer that *fraterculus* has the abdomen wholly yellow haired and has yellow or brownish bristles.

(4) Not mentioned in former descriptions of *fraterculus*.

(5) According to Bezzi (1) this spot is not present in *fraterculus*. Greene (3) who states that the adults are easily differentiated on wing pattern illustrates the spot for *A. fraterculus* but not for *A. ludens* or *A. serpentina* and indistinct for *A. striata*.

(6) In Wiedemann's description the arms are "in no way connected". Loew states that in Wiedemann's type the connection was present though not very distinct.

Río Piedras, Puerto Rico, reared by F. Seín, Jr., from *Spondias mombin* L. In the British Museum, London, England, and at the Insular Experiment Station, Río Piedras, Puerto Rico.

Mounted wings from which the drawings of the variations in pattern and slides from which the drawings of the posterior spiracles and the hairs or rays were made deposited at the Insular Experiment Station.

The egg: Length, 1.4 mm.; Width, 0.4 mm.; Spindle shaped with one end prolonged into a neck which usually swells somewhat into an ovoid head at its extremity, the other end bluntly pointed, (Figs. 8, 9 and 10). Egg membrane white, opaque, smooth and glossy. The egg is inserted in the fruit up to the shoulder, the head and neck protruding outside of the cuticle (Figs. 6–8 and 10). The larva emerges through a slit near the pointed end.

Described from eggs dissected out of fruits, from mature eggs dissected out of the female flies and from eggs deposited on the surface of fruits in cages.

The larva: Maximum length, 10 mm., width, 2 mm., at posterior end; cylindrical, tapering slightly towards cephalic end. When young, cream colored, usually turning later to a golden yellow. In addition to the head region, the body consists of 11 segments of about equal length; a ventral fusiform area on anterior portion of each of segments 2 or 3 to 11(7), (Fig. 16). Head, (Fig. 14), small, partly retractile, each side of the front bearing two broadly rounded somewhat flattened tubercles, the antennae(8) slightly larger; mouth hooks (Figs. 20–25), medium sized, first part rather slender, first and second parts black, second part shaped more frequently like the head of a hammer(9), third part with a dark brown infuscated area at base which fades to hyaline towards apices. Anterior spiracles small, yellowish, chitinized, with from 10 to 16 small rounded tubules(10) arranged in an irregular row, (Fig. 15). Posterior spiracles, (Figs. 17, 19 and 27), medium sized, each spiracle with three broad yellow entrances, each with a dark brown peritreme, entrances more frequently arranged so that the two above are parallel and the one below obliquely upturned(11), Figs. 17 and 19), but in some specimens all three entrances may converge, (Fig. 27). In some specimens the entrances may be described as short and thick, in others as longer and more slender. Hairs (rays) branched and well spaced as shown in (Fig. 17). Button large but indistinct. Above each spiracle two small tubercles in a transverse line and below, two small tubercles slightly wider apart and almost in a transverse line (12), (Fig. 26). The lower pair of tubercles is in some specimens located in a ridge, (Fig. 26, *a* and *b*), in others in two ridges (Fig. 26, *c* and *d*), and the innermost of the two tubercles is usually bifid (Fig. 26, *a* and *c*). Another pair of tubercles can usually be seen on the median line between the upper and the lower pair(13). Anal elevation large, rounded and with two prominent lobes.

(7) According to Greene (3) in *A. fraterculus* the fusiform area occurs on segments 4 to 11.

(8) Greene illustrates a somewhat differently shaped antenna.

(9) Greene's illustration shows it shaped somewhat like a bottle.

(10) According to Greene *A. fraterculus* has from 15 to 17 tubules, *A. striata* and *A. serpentina* go as high as 17 and *C. capitata* as low as 10.

(11) According to Greene the second is the only arrangement that occurs in *fraterculus*.

(12) According to Greene there is one tubercule below each spiracle.

(13) Greene does not consider them as bifid; this condition was first pointed out to the writer by Mr. F. H. Benjamin.

(14) Not mentioned by Greene.

Described from 500 full grown larvae from the same sources as the adults.

The puparium: Maximum length, 5.7 mm., width, 2 to 2.4 mm., cylindrical, yellowish, later turning to mahogany; 11 distinct segments, (Figs. 32–35). Anterior spiracles like those of the larva but darker and somewhat shrunk. Posterior spiracles (Fig. 36) medium sized, dark reddish, located in a faintly depressed area somewhat oval in shape, a broad flattened projection extending down between the upper end of the spiracular plates(15), each spiracle with three broad yellow entrances, each located on a well defined ridge; button small and indistinct. Anal plate large, dark and round.

Described from 500 specimens from the same source as the larva. Material from Panama (whence Greene drew his description) has also been examined.

Hosts: Hog plum, "jobo" *Spondias mombin* L.; "ciruela", *S. cirouella* Tussac and *S. purpurea* L., some mango varieties, *Mangifera indica* L., and rarely in "jobo de la India", *S. dulcis* Frost. Occasionally some may breed in guava, "guayaba", *Psidium guajava* L., and rose apple, "pomarrosa", *Jambos jambos* L.

Anastrepha unipuncta new species

The adults of this species can readily be differentiated from *A. fraterculus* Wied., var. *mombinpraeoptans* by the dark spot on the suture between the metathorax and the scutellum. The egg has no neck and is deposited entirely underneath the cuticle of the fruit. The larva has the hairs or rays in the posterior spiracles more numerous, closer together and somewhat less branched. No character has yet been found to distinguish the puparium. An occasional puparium may be formed inside the fruits in which the larvae have developed, a habit which has not been observed in *A. fraterculus* Wied., var. *mombinpraeoptans.*

The adult: Slightly darker than *A. fraterculus* Wied., var. *mombinpraeoptans* and similar in size; ovipositor very slightly longer and wider at the middle, (Fig. 42). Thorax (Fig. 5) dorsally a reddish amber or honey color the median mesoscutal vitta linear and faintly lighter than thorax; lateral and pleural vittae a dull greenish yellow. Pile on dorsal part of thorax all blackish (Fig. 38). A noticeable dark spot on the suture between the metathorax and the scutellum, (Figs. 5, 38 and 39) invariably present. Wing markings (Figs. 2 and 57–60), usually darker and more smoky and in some individuals different in pattern from *A. fraterculus* Wied., var. *mombinpraeoptans.* Basal band dark smoky. S shaped band dark smoky to near the r-m cross vein thence brownish yellow to cell Cu_1. In cell Cu_1 the two dark smoky spots frequently coalesce extending towards the base of the wing. When the basal and the S bands are not connected, the hyaline area between the two bands extends uninterruptedly towards the base of the wing, (Figs. 2 and 60). The connection between the S and the inverted V bands though strong in some individuals (Figs. 2 and 58) may be weak (Figs. 57 and 60) or lacking in others (Fig. 59). In many individuals

(15) According to Greene the area is hexagonal and the flattened projection is not present, it being specific for *A. striata.*

there are two slightly lighter areas in the basal band on either side of the humeral cross vein. In dried or in specimens preserved in alcohol the spot on the dorsum is always visible.

Described from over 500 specimens reared from the different fruits in which the insect breeds collected in different localities in Puerto Rico including the lower and the higher elevations. Specimens in the collection of the Insular Experiment Station, P. R., reared from guava in 1913 and identified as *A. fraterculus* Wied., have also been studied.

Type.—A single female; (P. R. Ac. No. 45–33), March 20, 1933, Río Piedras, Puerto Rico; reared by F. Seín, Jr., from *Psidium guajava* L. In the U. S. National Museum, Washington, D. C.

Paratypes.—Four female specimens; (P. R. Ac. No. 45–33), March 20, 1933, Río Piedras, Puerto Rico, reared by F. Seín, Jr., from *Psidium guajava* L. In the British Museum, London, England, and at the Insular Experiment Station, Río Piedras, Puerto Rico.

Mounted wings from which the drawings of the variations in pattern, and slides from which the drawings of the posterior spiracles and the hairs or rays were made deposited at the Insular Experiment Station.

The egg: Length, 1 mm., width, 0.3 mm. Spindle shaped, both ends bluntly pointed and one with reticulations which may be indistinct in some cases, (Figs. 11–13). Egg membrane opaque, smooth and glossy. Egg inserted in the fruit just underneath the cuticle, the reticulated end nearest to the cuticle.

Described from mature eggs dissected out of the female flies and from eggs laid in and on fruits in cages in the laboratory.

The larva: Similar in size and color and other characters to that of *A. fraterculus* Wied., var. *mombinpraeoptans* except that the bunches of hairs (rays) in the posterior spiracles are more numerous, closer together and not so branched, (Fig. 18), entrances more frequently convergent; number of tubules in anterior spiracles from 9 to 17, the lowest numbers have been found in rose apple and citrus and the highest also in citrus.

Described from 200 full grown larvae from the same source as the adults.

The puparium: Similar to that of *A. fraterculus* Wied., var. *mombinpraeoptans*. An occasional one may be formed inside the fruits in which the larvae have developed, a habit *A. fraterculus* Wied., var. *mombinpraeoptans* has not been observed to have.

Described from over 200 specimens from the same source as the larva.

Hosts: Guava "guayaba", *Psidum guajava* L.; rose apple, "pomarrosa", *Jambos jambos* L.; tropical almond, "almendra" *Terminalia catappa* L.; kunquat, *Fortunella margarita* (Champ) Swingle; star apple, "caimito", *Chysophyllum cainito* L.; zapodilla, "níspero", *Sapota achras* Mill.; custard apple or bullock's heart, "corazón", *Anona reticulata* L.; and beach plum, "hicaco", *Chrysobalanus icaco* L., occasionally, in the spring and early summer sporadically a few may breed in grapefruit, *Citrus maxima* Merril; sour orange, "naranja agria", *C. aurantium* L.; native and Valencia oranges, "chinas", *C. sinensis* L.

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PLATE X

Fig. 1.—*Anastrepha fraterculus* Wied., var. *mombinpræoptans,* right wing, greatly magnified.

Fig. 2.—*Anastrepha unipuncta* n. sp. right wing, same magnification as fig. 1; notice that the bands are darker and that the basal and the S shaped band are disconnected.

Fig. 3.—*Anastrepha fraterculus* Wied., from Argentina, right wing, same magnification as figs. 1 and 2; notice that the wing is larger than the other two, that the S shaped band and the inverted V bands are more slender and that they are disconnected; in color the Argentinean is similar to the *mombinpraeoptans* variety and both are lighter than *A. unipuncta.*

Fig. 4.—*Anastrepha fraterculus* Wied., var. *mombinpraeoptans,* dorsal view of female adult greatly magnified; notice the three bright longitudinal sulphur yellow stripes on the thorax.

Fig. 5.—*Anstrepha unipuncta* n. sp., dorsal view of thorax, magnification about the same as in fig. 4; notice the dark spot on the suture between the metathorax and the scutellum not present in fig. 4 and that the longitudinal stripes are dull and indistinct.

Fig. 6.—*Anastrepha fraterculus* Wied., var., *mombinpraeoptans,* the end of the egg protruding out of the cuticle of a green fruit, greatly magnified.

Fig. 7.—Same, the end of the egg protruding out of a ripe fruit.

Fig. 8.—Section of a green hog plum, *Spondias mombin* L., to show the egg as it is inserted by the female. In other fruits the egg is inserted in the same manner.

PLATE XI

Fig. 9.—*Anastrepha fraterculus* Wied., var. *mombinpraeoptans,* longitudinal section of egg, greatly magnified.

Fig. 10.—Same lateral view of egg with fruit tissues adhering to it as it usually appears when dissected out of fruits, not so greatly enlarged as Fig. 9.

Fig. 11.—*Anastrepha unipuncta,* n. sp., lateral view of egg showing reticulations at one end, magnification slightly more than Fig. 10 and very much less than Fig. 9.

Fig. 12.—Same, showing slight difference in shape and size.

Fig. 13.—Same, showing some variation in shape and reticulations indistinct.

Fig. 14.—*A. fraterculus* Wied., var., *mombinpraeoptans,* lateral view of head of larva showing: Mth, mouth; Oh, oral hook; a, antenna, ASp, anterior spiracle, greatly magnified.

Fig. 15.—Same, anterior spiracle of mature larva, lateral view, greatly magnified.

Fig. 16.—Same, lateral view of mature larva showing, VFa, ventral fusiform area, and 1 to 11, number of segments, greatly magnified.

Fig. 17.—Same, posterior spiracles of mature larva showing the hairs or rays well spaced and branched and the two entrances above parallel with the lower one obliquely upturned, greatly magnified.

Fig. 18.—*Anastrepha unipuncta,* n. sp. posterior spiracles of the female showing the hairs or rays more abundant, closer together and less branched than in Fig. 17, greatly magnified, entrances convergent.

Fig. 19.—*Anastrepha fraterculus* Wied., var., *mombinpraeoptans,* posterior spiracles of one third grown larva showing the two spiracular plates closer together than in the full grown larva in Fig. 17, but the hairs or rays about the same, greatly magnified.

Fig. 20.—Same, mouth hooks of the full grown larva, lateral view showing the three parts, greatly magnified.

Figs. 21–25.—Same, mouth hooks of full grown larva, first and second parts of different individuals showing variations in the shape, greatly magnified.

Fig. 26.—Same, posterior end of full grown larva showing the tubercles: a and b, in profile, located in one ridge; c and d, in profile, located in two ridges; a and c, in profile, with inner tubercles bifid, greatly magnified.

Fig. 27.—Same, posterior spiracles of the mature larva showing the entrances convergent, hairs or rays not shown, greatly magnified.

Figs. 28–31.—*Anastrepha unipuncta* n. sp., posterior spiracles of the mature larva showing the two upper entrances horizontal and the lower one obliquely upturned, hairs or rays not shown, greatly magnified.

Plate XII

Fig. 32.—*Anastrepha fraterculus* Wied., var., *mombinpraeoptans,* lateral view of puparium showing: PSp, posterior spiracles; An, anus; Sp, lateral spiracle; P, vertical cleavage line; O, horizontal cleavage line; ASp, anterior spiracle; 1 to 11, number of segments, greatly magnified.

Fig. 33.—Same, lateral view of opened puparium after the emergence of the fly, ASp, anterior spiracle, greatly magnified.

Fig. 34.—Same, dorsal view of puparium showing: Asp, anterior spiracle; Mth, mouth; PSp, posterior spiracle, greatly magnified.

Fig. 35.—Same, ventral view of puparium showing AnP, the anal plate, greatly magnified.

Fig. 36.—Same, posterior spiracles of the puparium showing the broad flattened projection extending down between the upper end of the spiracular plates, greatly magnified.

Fig. 37.—Same, dorsal view of thorax showing the distribution of the dark colored pile, the whitish pile on the median mesoscutal vitta not showing, greatly magnified.

Fig. 38.—*Anastrepha unipuncta,* n. sp., dorsal view of thorax showing the distribution of the dark colored pile and the spot on the suture between the metathorax and the scutellum, greatly magnified.

Fig. 39.—Same, a variation in the shape of the spot between the metathorax and the scutellum, greatly magnified.

Fig. 40.—*Anastrepha fraterculus* Wied., var. *mombinpraeoptans,* external genitalia of the male showing the claspers, greatly magnified. The external genitalia of *A. unipuncta* show identical characters.

Fig. 41.—Same, lateral view of the ovipositor, greatly magnified.

Fig. 42.—*Anastrepha unipuncta,* n. sp., lateral view of the ovipositor, same magnification as Fig. 41; notice the difference in shape and size, Fig. 42 being wider at the middle and slightly longer than Fig. 41.

Plate XIII

Figs. 43 to 51.—*Anastrepha fraterculus* Wied., var. *mombinpraeoptans,* right wing of individuals showing variations in pattern, somewhat diagrammatic, greatly magnified.

Fig. 43.—Showing the connection between the S and the inverted V bands very weak.

Fig. 44.—The S band widening downwards and the inverted V band widening at the apex to make a wide connection.

Fig. 45.—The S and the inverted V bands connected at two points.

Fig. 46.—A wide connection between the S and the inverted V bands and the two arms of the inverted V band connected along the posterior margin of the wing.

Fig. 47.—Same, but the connection between the two bands still greater.

Fig. 48.—Same, but the arms of the inverted V band disconnected along the posterior margin of the wing.

Fig. 49.—The S and the inverted V bands connected at two points and the arms of the inverted V band connected along the posterior margin of the wing.

Fig. 50.—Same, but the arms of the inverted V band not connected along the posterior margin of the wing.

Fig. 51.—Same, the S and the inverted V bands almost connected near the tip of the wing in a striking manner.

Plate XIV

Figs. 52 to 56.—*Anastrepha fraterculus* Wied., var. *mombinpraeoptans*, right wing of individuals showing variations in pattern, greatly magnified, somewhat diagrammatic.

Fig. 52.—A very wide connection between the S and the inverted V bands and a striking curve of the outer arm of the inverted V band.

Fig. 53 and 54.—Breaking up of the S and the inverted V bands by vacuoles.

Fig. 55.—The two arms of the inverted V band disconnected somewhat as described for *A. fraterculus* by Wiedemann in Brazil.

Fig. 56.—The two halves of the S band disconnected, a most unusual condition.

Figs. 57–60.—*Anastrepha unipuncta* n. sp., right wing of individuals showing variations in pattern, greatly magnified, somewhat diagrammatic.

Figs. 57 & 58.—A pattern similar to that of *A. fraterculus* Wied., var., *mombinpraeoptans*, (Fig. 1) differing from it only in being darker.

Fig. 59.—The S and the inverted V bands entirely disconnnected, a condition seldom if ever occurring in *A. fraterculus* Wied., var. *mombinpraeoptans*.

Fig. 60.—The basal and the S bands entirely disconnected, a condition not observed in *A. fraterculus* Wied., var., *mombinpraeoptans*.

PLATE X.

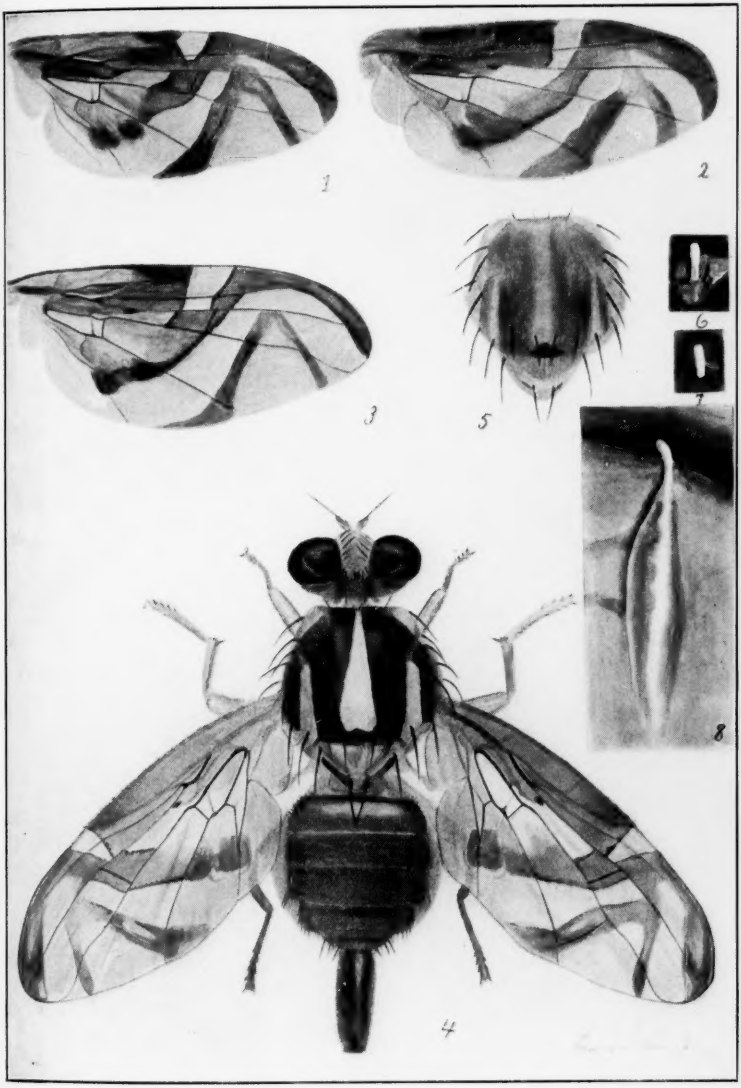


PLATE XI.

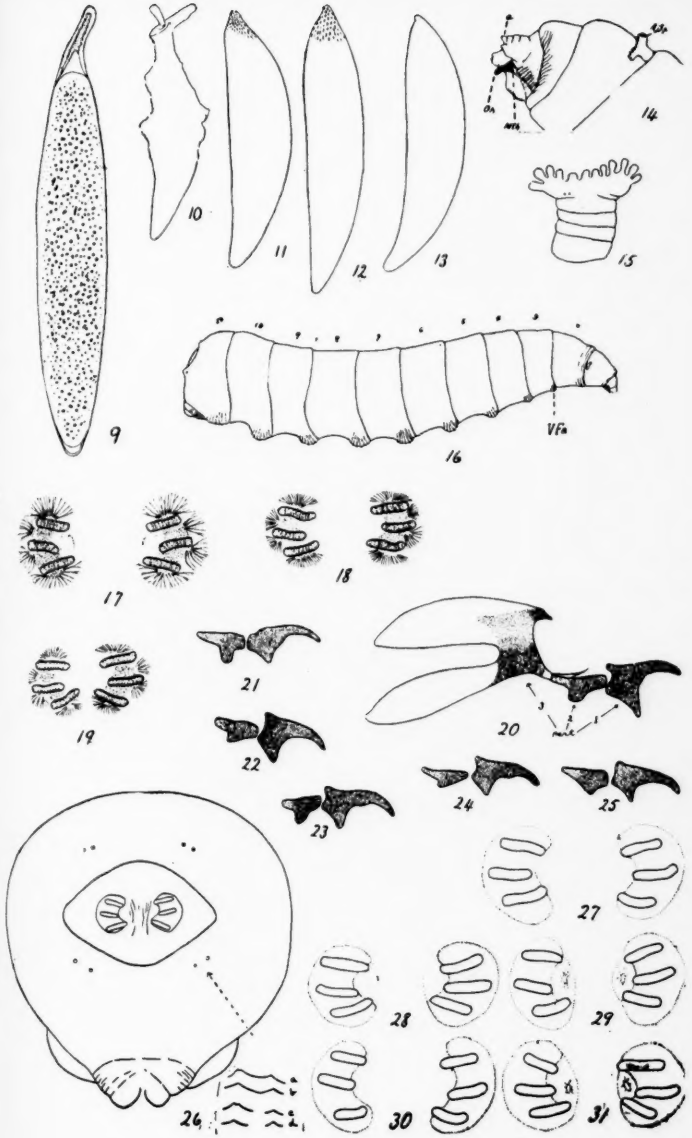
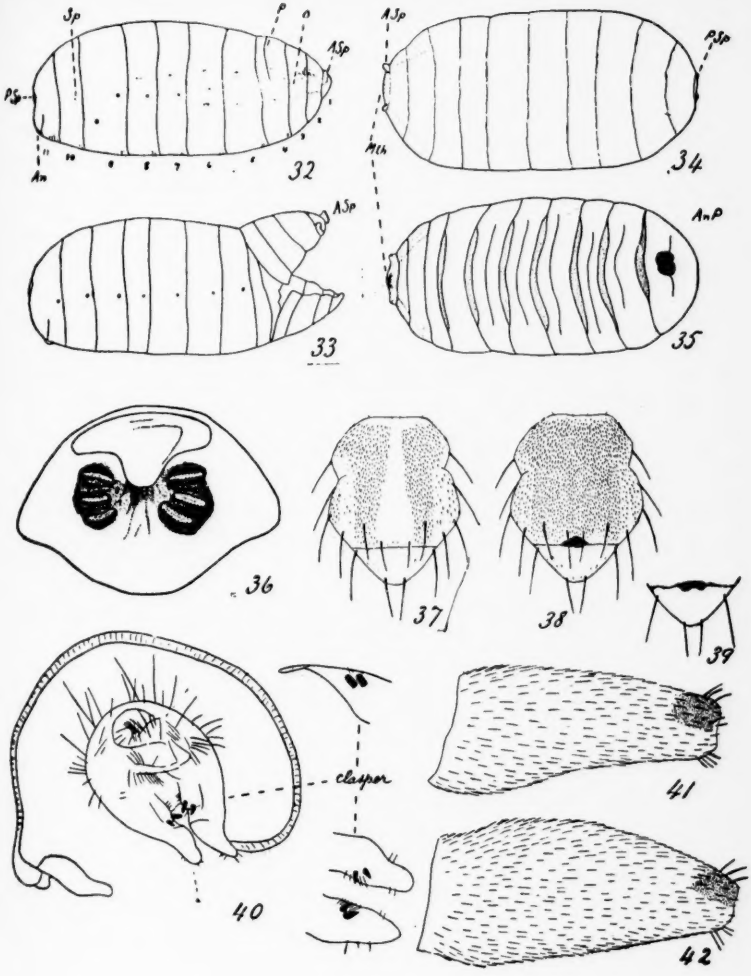


PLATE XII.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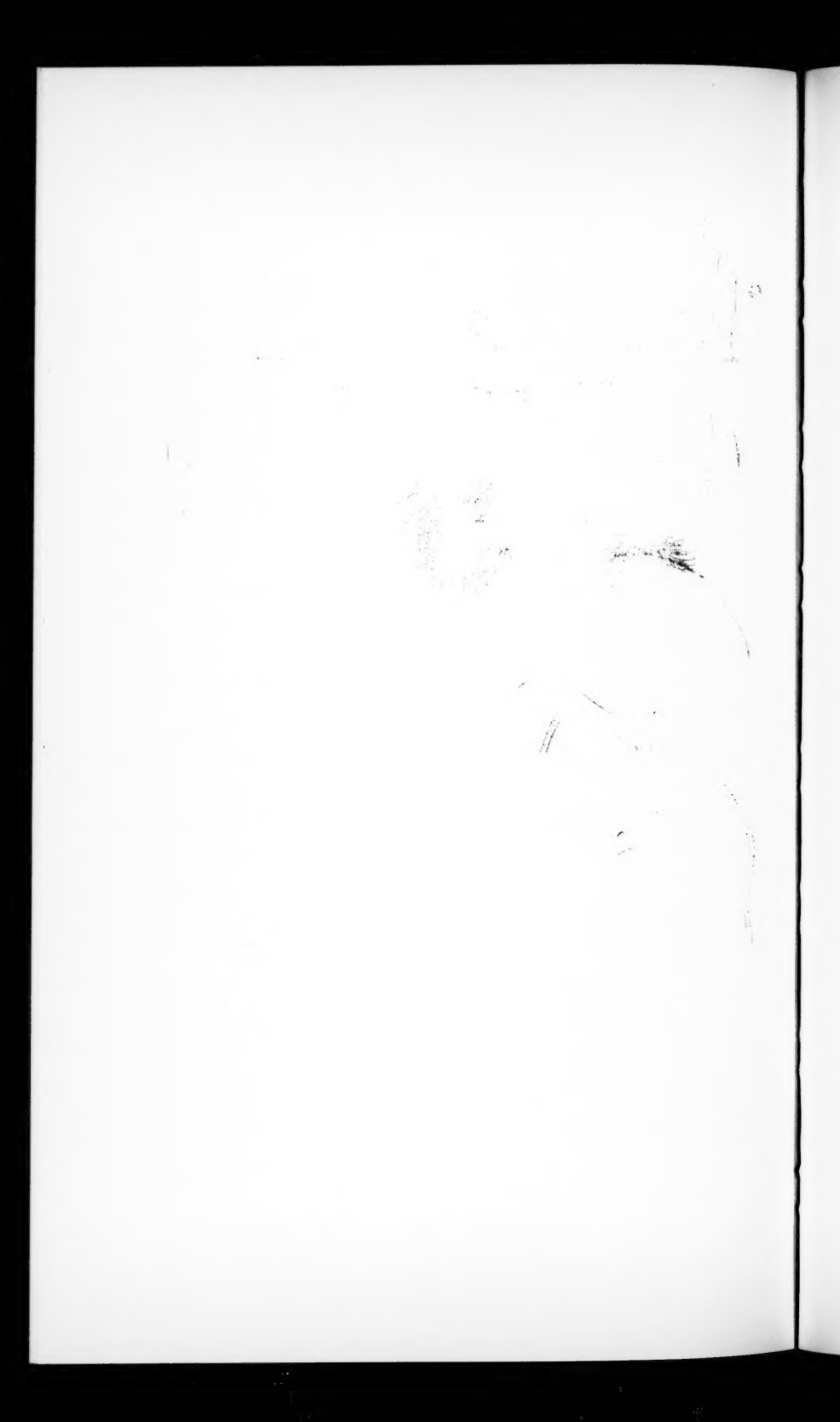


PLATE XIII.

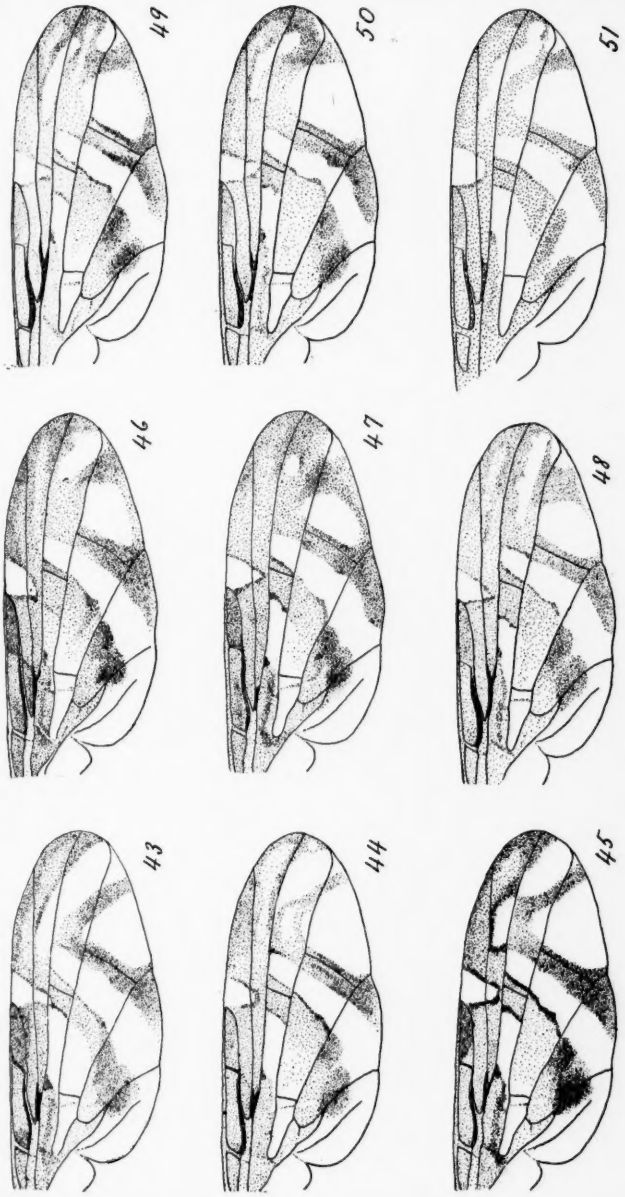
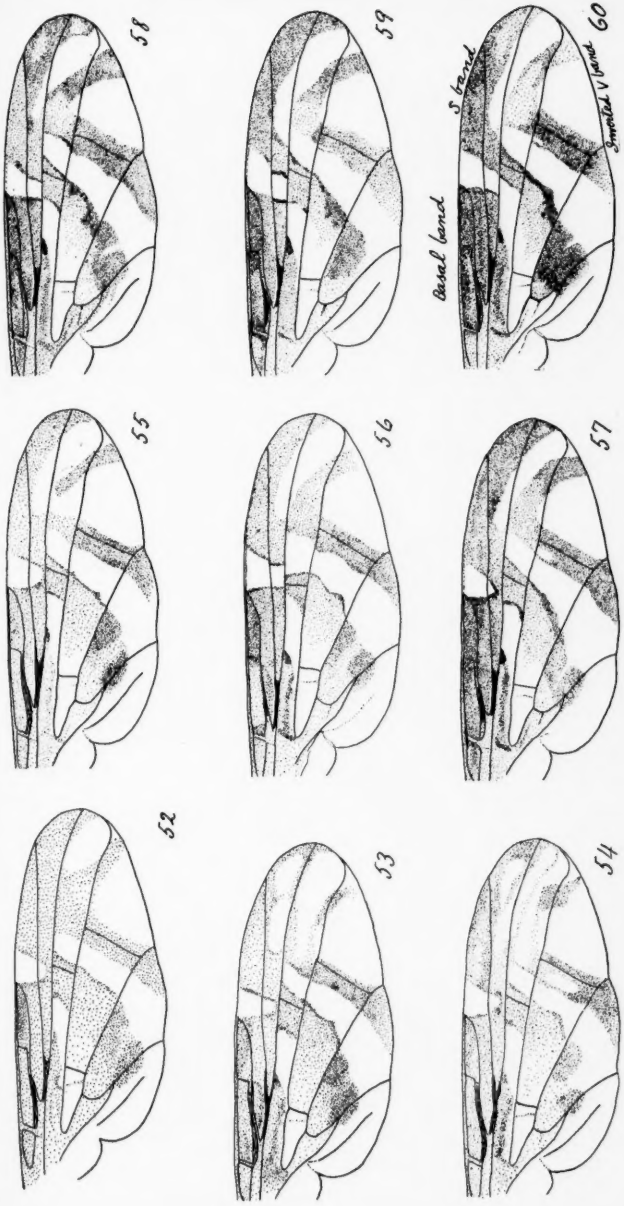


PLATE XIV.



THE EXTENT TO WHICH THE PRACTICE OF NOT BURNING CANE TRASH HAS BEEN ADOPTED IN PUERTO RICO

By GEORGE N. WOLCOTT, *Entomologist*,
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For many years, most entomologists working on the problem of the control of the sugar-cane moth stalk borer, *Diatraea saccharalis* F., have been of the opinion that the burning of cane trash in the field, either before or after harvesting, favored the borer because the fire destroyed its natural enemy, the egg-parasite, *Trichogramma minutum* Riley, and have therefore unceasingly recommended to cane growers that the trash should not be burned when the fields are to be ratooned. Only in Puerto Rico have these recommendations been at all widely adopted, but no definite data heretofore have been available to show the extent to which the planters were following the practise of cutting cane without burning the trash, and raking it into alternate rows to permit of cultivation and irrigation of the ratoon cane.

On April 3d, 4th and 5th, 1933, the writer, accompanied by Mr. Richard Faxon, in charge of the local unit of the federal Bureau of Plant Quarantine, and Mr. U. C. Loftin, Senior Entomologist of Cotton Insect Investigations, U. S. Bureau of Entomology, made a trip around the island, and noted every field readily observable from the road in which the trash had, or had not, been burned. Before giving the figures, it should be noted that non-burning the trash is essentially a negative practise, and that the trash had not been burned at the time of observation does not by any means indicate or prove that it might not be burned later. To more than compensate for this error, due to not being able to predict what might happen in the future, is the fact that if the trash is burned before cutting, this is readily observable even before the cane is cut, and is given credit under the heading of "burned". Furthermore, it is impossible to determine until a field is actually being plowed, whether it is to be left for ratoons or plowed for planting, and it is quite possible that some fields recorded as "burned" will eventually be plowed, and should not have been entered. No entomologist has considered recommending non-burning of trash in fields to be plowed for planting, yet one field was observed at Central Mercedita, Ponce, which was being fitted for planting, and in which, very obviously, the trash had not been burned. It should also be noted that the practise of burning cane

before cutting is most exceptional in Puerto Rico, yet it had been rather widely adopted this year in the northeastern corner of the island, where the damage to standing cane caused by the hurricane of San Ciprián, September 26–27, 1932, was greatest. In ordinary years, such a practise would practically never be followed in this part of the island.

In further explanation of the method used in making the observations, it should be stated that a field is considered to be any area, however large or small, receiving the same treatment at the same time. The enormous differences in size of field by this definition, might introduce a considerable error if only a few fields had been observed; but as the observations numbered five hundred four, it is considered that the figures as given present an essentially true picture. If the trash is burned in part of a field, and not burned in the other part, for the purpose of this investigation it is considered to be two fields.

Method of Disposal of Cane Trash in Fields to be Ratooned in Puerto Rico, observed at the height of the grinding season (April 3, 4 and 5) 1933.

Region	Trash not burned	Trash burned
San Juan to Maunabo (Northeast coast)	115	32
Maunabo to Ponce (Southeast coast)	81	7
Ponce to Mayagüez (Southwest coast)	85	14
Mayagüez to San Juan (Northwest coast)	146	24
Totals	227	77
Per cent	84.7	15.3

A YEAR'S EXPERIENCE WITH THE COTTONY CUSHION SCALE IN PUERTO RICO *

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and
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The most complete yet succinct account of the Cottony Cushion Scale, or as it was earlier generally called, the Fluted Scale, and its accidental introduction into California, is that written almost a generation ago by Dr. C. L. Marlatt(**1**). This is quoted below entire, with one interpelating quotation from Dr. L. O. Howard, as it gives a picture of how the scale and its control were regarded and how this affected the then pioneering industry of citrus fruit production in California.

"Of all the scale insects attacking citrus plants, this species, (*Icerya purchasi* Maskell) is perhaps the most notable, not so much from the damage now occasioned by it as from the problems of control which it has brought to the front and the international character of the work which it has occasioned.

"The facts indicate that Australia is undoubtedly its original home, from whence it was introduced on Australian plants into New Zealand, Cape Town, South Africa, and California at about the same time. The evidence points to its introduction into California about the year 1868 on *Acacia latifolia.* It is a very hardy insect, will live for some time without food, and thrives on a great number of food plants. In California it spread rather rapidly, and by 1886 had become the most destructive of orange scale pests. The damage occasioned by it was of such a serious character as to threaten the entire citrus industry of the Pacific coast. The nature and habits of this insect made it almost impervious to any insecticide washes, and the orange growers of California were rapidly losing heart.

"In 1889 however, through the agency of Mr. Albert Koebele, an assistant of this office (the U. S. Bureau of Entomology), the natural

* Some of the observations on which this paper is based were made by one writer, some by the other, but in most cases they were made jointly by both at the same time. All of the rearing work, of the scale and of the lady-beetles, has been conducted by the junior author. For the past year, the senior author has been in charge of the work and the MS was written by him.

ladybird enemy of the fluted scale was discovered in Australia and imported into California. This ladybird *Novius (Vedalia) cardinalis*, multiplied prodigiously, and in a very short time practically exterminated the fluted scale, saved the State of California annual damage amounting to hundreds of thousands of dollars, and removed this scale insect from the roll of dreaded injurious species."(**1**) Dr. Howard has thus evaluated this accomplishment: "This dramatic and extremely useful bit of work was a great thing for scientific economic entomology. So striking a success may probably never again be achieved in this country."(**2**)

"The beneficial results derived from this ladybird have not been confined to California. Through the agency of this Department (the U. S. Bureau of Entomolgy), and in cooperation with the California State authorities, this ladybird has been sent to South Africa, Egypt, Portugal, and Italy, and in each of these countries its introduction has been followed by similar beneficial results in the control of the fluted scale.

"While the fluted scale, at the time or soon after its injurious record in California, gained access to several foreign countries, very fortunately Florida and the Gulf districts remained long free from it.

"The first and presumably only introduction of this insect into Florida was an intentional one, though not malicious, and illustrates the risk run in importations of beneficial insects undertaken by persons unfamiliar with the subject. A nurseryman of Hillsboro County, Fla., hoping to duplicate against the common Florida scale insects the wonderful work of the imported Australian ladybird against the fluted scale in California and, ignorant of the fact that the ladybird in question did not feed on any of the armored scales which he especially wished to have controlled by it, got one of the county horticultural commissioners of California to ship him a lot of these ladybirds, together with some of the fluted scale as food. The whole lot was liberated on his premises and resulted, naturally enough, in stocking some of his trees very thoroughly with the fluted scale. The infestation coming to his attention, he sent, in June, 1894, specimens to the Division of Entomology and they were promply determined as the dreaded California scale pest. Fortunately, the nurseryman in question realized the enormity of his offense and took, at Dr. Howard's earnest suggestion, immediate and active measures to exterminate the fluted scale on his premises, ultimately taking out and burning the trees.

"It was hoped that extermination has been effected, but four years later (1898) the fluted scale was again received from the same dis-

triet. In view of its quite general spread, as reported, in the immediate region, it seemed improbable that it could be easily exterminated, and the introduction of the Australian ladybird was urgently advised. During the spring and summer of 1899 the ladybird in question was successfully colonized in Florida by Mr. Gossard, with the assistance of Mr. Craw.

"The fluted scale in Florida evidently does not multiply as rapidly as it does in California. Furthermore, as shown by Mr. Gossard, it is attacked by a fungous disease which appears suddenly in July and results in the death of from 25 to 70 per cent of the partly grown scales. We may hope that with the aid of this disease, and by means of the prompt introduction of its natural enemy, the fluted scales will never play the role in Florida which it originally did in California.

"The habits and transformations of the fluted scale closely parallel those of the species of *Lecanium* already described. The general appearance of the insect, however, is strikingly dissimilar, owing to the waxy excretions from the ventral plate of the adult female insect. There are ribbed, or fluted, from whence the insect takes it name, and become the receptacle of a vast number of eggs, a single female being the possible parent of more than a thousand young. The waxy material constituting the egg sac issues from countless pores on the under side of the body, especially along the posterior and lateral edges. As this secretion accumulates the body is lifted, so that ultimately the insect appears to be standing almost on its head, or nearly at right angles to the bark. The eggs are laid in the waxy secretion as it is formed, the waxy fluted mass often becoming from two to two and one-half times as long as the insect itself. The young are of reddish color, very active, and spread by their own efforts and by the agency of the winds, birds, and other insects. The female insect is, for the most part, a reddish orange, more or less spotted with white or lemon.

"The early stages of the male are similar to the corresponding stages of the female. Before appearing as an adult, the male insect secretes itself in some crack in the bark, or in the ground, and exudes a waxy covering, which forms a sort of cocoon, in which the transformations are undergone, first into the pupa and then into the adult insect. The winged male is rather large for a coccid, and has a reddish body with smoky wings.

"The rate of growth of the fluted scale is comparatively slow, and it does not normally have more than three generations annually.

This insect is quite active, the female traveling and moving about very freely nearly up to the time when she finally settles for egg-laying. The male is active up to the time when it settles down to makes its cocoon.

"The fluted scale exudes a great quantity of honeydew, and trees badly attacked by it are covered with the sooty fungus, characteristic of the black scale and the white fly.

"The remedy for this scale insect is always and emphatically to secure at once its natural and efficient enemy, the *Novius cardinalis*. Where this insect can not readily be secured, the scale may be kept in check by frequent sprayings with the kerosene or resin washes. Fumigation is comparatively ineffective against it, because the eggs are not destroyed by this treatment. Spraying is, for the same reason, effective only when it is repeated sufficiently often to destroy the young as they hatch."(1)

The above account of the cottony cushion scale and of its spectacular control in California has been reprinted here to indicate how generally it is considered that the problem of control of this pest is thoroly and completely solved. Yet upon examining the more recent publications from California, one discovers that control by the lady-beetle *Novius, Vedalia*, or *Rodolia cardinalis*, as it is now called, is by no means as effective as the earlier statements would lead one to suppose.

For instance, Prof. H. J. Quayle states that:

"While the cottony cushion scale is at present a pest of comparatively little consequence, it is still one of the commonest insects inquired about throughout the entire length of the State where citrus trees are grown. While the *cardinalis* is pretty well distributed over the State, and often appears unaided in an infestation of cottony cushion scale, yet in many cases it does not occur, and neither does the scale become very abundant. The checking of the scale in such cases must be accounted for through some other factors. Sometimes, too, the beetle is slow in getting the scale under control. On the station grounds at Riverside fifty or seventy-five orange trees have been infested with the cottony cushion scale, as bad as occurred when the insect was at its height, for at least four years. During this time also the ladybird beetle has been present. The scale becomes very abundant each spring when the *cardinalis* begins work and effectively checks them. The beetles are present in April, May, and June, and disappear in July. Some young scales are left and those have a chance to multiply and severely infest the trees again

before the *cardinalis* appears in the spring. This has been the history of the infestation for the past four years."(**3**)

Nor is the relative value of the parasites introduced by Koebele finally settled, for, to quote from a recent book by Dr. E. O. Essig: "The dipterous parasite of the cottony cushion scale, *Cryptochaetum iceryae* (Williston), was one of the natural enemies of *Icerya purchasi* Mask., introduced by F. S. Crawford and Albert Koebele from Australia into California in 1888–9. The adults are 1.5 mm. long, the head and the thorax metallic dark blue, and the abdomen iridescent green. They are rather slow in movement, crawling slowly over the cottony cushion scale inserting one to several minute, oblong, oval, smooth, pearly white eggs preferably in the half grown hosts. It is thought that a single female may lay as many as 200 eggs. The young larvae are curious, semitransparent elongated maggots with black mouth hooks, the anterior half of the body bare, the posterior half ciliated and with two long tail-like processes often twice the length of the body. The full-grown larvae are quite different. The body becomes pear-shaped with two horn-like tracheae and the tail-like processes extended to four or five times the length of the body. The color becomes reddish from the contents in the alimentary canal. The larvae live freely within the body cavity of the host feeding on the body fluids and apparently not seriously inconveniencing it; upon reaching maturity, however, the host is eventually killed. Several larvae may occur in a single scale insect. Pupation occurs within the dead body of the host. The puparia are yellow or reddish brown, oval, 2 mm. long, with two horn-like projections. There are five or six generations a year. This parasite is often the most important natural check on the cottony cushion scale, but because of its small size and the concealed manner of attack, it has not been given due credit for its efficiency. In the San Francisco Bay region it persists where the vedalia has long since passed away and keeps the scale insect under almost perfect control. Practically every lot of the scale sent to the University for examination shows the work of the fly and it is with great difficulty that living specimens of this once common and abundant scale insect can be secured for student study. In Southern California too this parasite has done much of the work claimed for the vedalia."(**4**)

Indeed, the whole problem of the cottony cushion scale, which was at one time thought to be finally settled and decided, is in fact still very much of a problem. If this is the condition in California, where the insect has been present for so long, and investigators have

been working on it ever since it first appeared, one may anticipate that its status in a new and entirely different environment may be even more subject to unusual and unexpected conditions.

The first published record of the cottony cushion scale in Puerto Rico is a note by Dr. W. A. Hoffman (**5**), of the School of Tropical Medicine in San Juan, who first observed it on a hedge of casuarina or Australian pine, *Casuarina equisetifolia,* in the patio of the School, later noting it generally on this host elsewhere in San Juan. (See Pl. XV.) This was not the first known occurrence, however, for it had previously been collected on rose bushes in Santurce, a suburb of San Juan, over a year previously, and determined by Dr. Harold Morrison of the U. S. National Museum at Washington. This record was not published until July, 1932(**6**), and then without special comment among hundreds of others, mostly of common or well-known insects. The early developments in the story of the cottony cushion scale in Puerto Rico are best told in an unpublished MS prepared by Dr. M. D. Leonard, at that time Chief of the Department of Entomology at the Insular Station. He said,—

"On October 21, 1931, Edmundo Martínez of the Insular Forest Service brought a small twig of Casuarina to the Station bearing two specimens of the cottony cushion scale. These had been brought to his Station by some woman of unknown name and address in Santurce, for identification. The extent of the infestation was not known. I sent these two specimens to Dr. Morrison under date of October 21, 1931 (the same day) for determination since I was not sure but that this might be *Icerya montserratensis.* I told Mr. Martínez at the time, however, that this was probably *purchasi,* the injurious citrus species, and urged that he and the other foresters be on the lookout for it on casuarina. I myself had often looked at the casuarina at the Forestal in Río Piedras but had seen no evidence of infestation by this or any other insect.

"On February 16 or 17, 1932, I received from Dr. Morrison a letter dated February 5, confirming my determination of the casuarina specimens as *I. purchasi.* I saw Mr. Martínez a day or two later at the Post Office in Río Piedras and told him of this and asked again that the foresters be on the lookout for it.

"At about the same time I told Mr. Faxon, Chief of the Federal Plant Quarantine Office, of this determination and asked that he and his inspectors be on the lookout for *purchasi* on both casuarina and citrus during their regular grove inspections.

"From then on I personally examined a number of casuarina trees and hedges around Santurce but saw none until the first week

in March when in company with Mr. C. E. Pemberton, Chief Entomologist of the Hawaiian Sugar Planters' Experiment Station, a light infestation was found on a few casuarina trees next to the Clínica Miramar at Stop 10, in Santurce. These were for the most part unhealthy looking insects and a considerable proportion of the few there had been eaten out by something.

"At this time I told Mr. Pemberton of the occurrence of *purchasi* here on roses and casuarina (both determined by Dr. Morrison) and concluded that it was so scarce and so restricted that nothing be done about control at that time.

"When Dr. Wolcott was in San Juan on March 4 and 5 to attend the International Sugar Cane Technologists' Congress, the infestation on the casuarina hedge at the Clínica Miramar had not yet been noticed. I next saw him on March 11 during the trip of the Technologists around the Island and on the 12th at Guánica told him of the occurrence of *purchasi* on roses and casuarina (3 infestations total only observed to date) and we examined many casuarinas in company with Dr. Pemberton. I still did not think it worth while to give this any publicity.

"I examined casuarinas at all stops in the Island tour between that date and March 15 but with negative results.

"On March 24, I believe it was, Dr. Wolcott wrote Commissioner Colón advising him, on my say-so, of the presence of *purchasi* in Puerto Rico and advised immediate extermination. I did not know this had been done however, until March 29. On this date I visited Mr. Barbour, Chief of the Insular Forest Service, to tell him that we had just recently discovered that the casuarina hedge in the Parque Muñoz Rivera in San Juan was generally infested and that light infestations occurred on one or two other hedges near the Union Club in Santurce. We also examined again carefully all the casuarina seedlings and larger trees at the Forestal with negative results. Mr. Barbour showed me a letter from Dr. Wolcott under date of March 19 urging that he watch carefully his casuarina seedlings in the nursery and saying that he had officially notified the Commissioner of the presence of *purchasi*.

"About this time Mr. Seín stated that he had found a rather bad infestation of what he had taken to be *Orthesia insignis* on the large casuarina hedge of the Colegio Puertorriqueño at Stop 15 in Santurce. The date was on February 26. This was now determined however as *I. purchasi*. He had recommended nicotine sulphate and soap. Some "gallego" plants, *Polysias Guilfoylei*, were also infested there.

"Based on Dr. Wolcott's notice of March 24th to the Commissioner, a meeting of the Insular Plant Quarantine Board was called on March 31 to consider possible measures to be taken against the cottony cushion scale. The history to-date in Puerto Rico was briefly reviewed and a resolution was made by Mr. López Domínguez and adopted to make a more thoro survey than had already been made of citrus and of casuarina especially in the vicinity of citrus groves as soon as practical and to determine, if possible, what agents may be holding the pest wherever it occurs.

"The next day, April 1, I visited Mr. Luciano's home in Santurce since Mr. Luciano had written me the day before that he had just observed parasites of the cottony cushion scale working there. There were present besides myself and Mr. Luciano, Messrs. Pemberton, and Anderson and Mills of the U. S. Plant Quarantine and Control Administration Office. A dipterous maggot was found working in the hollowed-out egg-sacks of the scale on the rose bushes and in some cases 3 or 4 puparia present in one empty egg-sack. Mr. Luciano stated that he had observed these rose bushes infested for about 2 years now and that the infestation was lighter now than formerly. There was no infestation on a number of casuarinas present in his garden. Two or three days later several small Phorid flies emerged from specimens of infested scales. This may possibly be *Syneura cocciphila* described from *I. purchasi* in 1895, from Mexico. Specimens were sent for determination to Washington thru Mr. Faxon's office by the boat of April 7.

"On April 2, Mr. Pemberton and I found that a number of scales in the lightly infested casuarina hedge alongside of the Olimpo Court Apartments at Stop 10, Santurce, were parasitized by the Phorid fly.

"Upon arrival at the Station Mr. K. M. Fletcher was there with a badly infested branch from his grapefruit grove at Palo Seco. He said a number of trees were infested, several badly so. Messrs. Pemberton and Seín and myself at once visited his grove and found that at least a dozen or fifteen trees had some branches badly encrusted with the insects and a number of other trees were lightly infested. Most of the trouble occurred on the first two rows next to a large bamboo windbreak along the road. A number of pigeon pea bushes next to the first row were also considerably infested. Mr. Fletcher stated that he had noticed this infestation over a month ago but it had just lately become much worse. He claims to have seen this insect present in his grove off and on in small numbers for the last

20 years. He had already scrubbed with brushes the larger branches of several trees previously, he said, badly infested.

"I recommended an oil or nicotine and soap spray at once and the immediate introduction of the Australian ladybird beetle.

"*April 4, 1932.* In the morning I went with Mr. Fletcher and Mr. Wildman (of the Isabela grove adjoining Mr. Fletcher's place) to see Commissioner Colón, and recommended introduction of the Vedalia beetles. I prepared a cable at once to the Florida State Plant Board requesting a prompt shipment of the beetles by air-mail.

"In the afternoon Fletcher's grove was again examined in company with representatives of the Insular and Federal Quarantine Services, Mr. Pemberton and Mr. Sims of the Nitrates Agencies.

"During the next few days I told several of the leading citrus growers about the infestation at Fletcher's and showed them specimens of the insect.

"On April 8, in company with Messrs. Anderson and Mills, of the Federal Plant Quarantine Office, we looked over Mr. John Kohn's (at Bayamón) casuarina windbreak and adjoining grape fruit trees as well as a number of rose bushes. Farther along the same road we found a light infestation on several trees in a large long casuarina windbreak and several grape fruit trees adjoining these as far as one tree in the 4th row from the windbreak lightly infested also. The Manager could not be located that afternoon.

"By previous arrangement I received from the Post Office in San Juan that night the shipment of 150 Vedalia puparia from Florida. They left Gainesville on the afternoon of the 5th.

"*April 9, 1932.* I had arranged to distribute the Vedalias in Mr. Fletcher's grove the first thing in the morning but was instructed by the Director to await the arrival of Dr. Wolcott who had been put in charge of the cottony cushion scale campaign by order of the Commissioner.

"*April 10, 1932.* The Director, Dr. Wolcott and I, released most of the Vedalias in Fletcher's grove in the morning—twelve boxes of them. Two boxes were put out on infested trees recently discovered in the adjoining Isabela grove and two were taken back to the Station. We then visited Mr. John Kohn and later arranged with the Manager of the Guildermeister grove nearby to start spraying with oil at once."

All the known occurrences of the cottony cushion scale in Puerto Rico up to that time were in San Juan and Santurce, or in citrus groves a few miles west along the coast, and widely separated by swampy marsh land, pasture or cane fields from the main citrus

producing section of the Island. The area was so limited in extent that for a time it seemed possible that the insect might be absolutely exterminated, if effective measures could be brought to bear upon it. The real difficulty was to determine what measures would actually be effective in extermination. A study of available literature showed only control measures, not extermination. By general admission, the lady-beetle *Rodolia* was only relatively effective, always leaving a few scales after cleaning up major infestations. Spraying was admittedly ineffective, and recommendations as to what to spray were vague and unsatisfactory. All that one could be sure of was that pruning of infested branches and destruction by fire of infested hosts would certainly eliminate those scales at least. Such treatment was quite practical in some cases, but hardly applicable generally in Isabela Grove, the largest single citrus property on the Island. As a matter of fact, however, the infestation in this grove was soon found to be so general that both spraying and pruning were generally adopted, and temporarily held the pest in check. In the adjoining grove, Mr. Fletcher had had little success in spraying with prepared oil sprays, consequently the old fashioned "cold-stirred" emulsion, with an excess of whale oil soap, was used in Isabela Grove.

Thru the co-operation of Mr. Fletcher and Mr. Kohn, a power sprayer was made available for immediate use by the Department of Agriculture in spraying casuarinas in San Juan, and as soon as funds were made available in the next fiscal year, a new power sprayer was purchased for this work. The conduct of spraying operations was under the supervision of Mr. Adolfo Mayoral, who previously had considerable orchard-spraying experience. He carried on extensive experiments to determine the relative merit of various sprays, and as a result, later sprayings were confined to the use of "Kerecide", a local preparation of standard composition which used fusel oil as stabilizer. His experiments showed that no spray is of much value during showery or rainy weather; but during dry weather, this heavy oil spray gives close to 100 per cent control. San Juan is an island, and most of the infestations in Santurce are close to the ocean, in some cases the casuarina trees being actually on the beach. It is under such conditions that the heavy oils give best results. Little is known about the effectiveness of this or other sprays under inland conditions, for up to the present no similarly extensive inland infestations have been available for experimentation.

Spraying and pruning operations having been gotten under way in localities where infestations were known to exist, the next step was to determine, if possible, all infestations. All available means

of publicity were used. Dr. Jaime Bagué, Sub-Commissioner of Agriculture, made announcements over the local radio broadcasting station. He also supervised the preparation of a poster, showing by reproductions of photographs of the insect on casuarina, what the insect looked like and requesting that all suspicious material be submitted for inspection. The text of the poster is as follows:

GRAVE PELIGRO PARA NUESTRA AGRICULTURA

La Cochinilla Blanca ha aparecido recientemente en los pinos australianos, rosales y toronjales de San Juan y sus cercanías.

Esta plaga es sumamente peligrosa; pues en una época casi acabó con los naranjos en el Estado de California.

Si usted encuentra dicho insecto en su jardín o en su huerto, ponga varios ejemplares en un frasco y envíelo a la Estación Experimental Insular, Río Piedras, P. R.

Coopere con nosotros a salvar la industria de toronjas de Puerto Rico que representa millones de dólares para el país.

A short descriptive article was circulated by both the fruit-growers' organizations, and write-ups appeared in San Juan newspapers. The aid of the Boy Scouts of the San Juan region was enlisted. Regional meetings of the Agricultural Agents were held in Río Piedras, Isabela, Ponce and Guayama, at which they were shown photographs of the insect (no live material was carried around the Island), and instructed to be on the constant look-out for infestations. While en route between these meetings, the senior writer inspected many casuarina trees, especially along the east and northeast coast. Later, a special inspection was made of the casuarinas and orange trees along the beach east from San Juan as far as Río Grande, the results being entirely negative.

The immediate returns from this publicity were encouragingly meagre. A few spider webs on casuarina needles were submitted by one anxious citrus grower, for these webs in size and color at least superficially resemble mature scales. Mr. Mariano Mari, in charge of the Demonstration Farm near Arecibo, noted an extensive infestation of the native cottony scale, *Icerya montserratensis* Riley & Howard, on orange, which he thought might be mixed with *Icerya purchasi* because many of the scales lacked the long waxy projections secreted by the native species. (See Plate XVI.) His suspicion was shown to be justified, when, a few days later, another infestation of *Icerya montserratensis,* on a single citrus tree at the Poultry Sub-Station at Pueblo Viejo, was discovered to be mixed with the Australian species. Several other large infestations were soon afterwards found in Pueblo Viejo, and a number of infestations in the

main Bayamón citrus district. A suburban resident on the Trujillo Alto road reported some scale on a rose bush which had been presented to him by a friend in Santurce. Scales were also found on the casuarinas besides the Las Monjas racetrack between Río Piedras and Santurce. All of these new records, however, were in the immediate vicinity of San Juan, and except in the one case where the scale had obviously been carried on the host, were to the west and southwest. No infestations were found to the east or far to the south, indicating that normal dispersion was resulting from the prevailing winds (from the east and northeast), and that this was by far the most important single factor in dispersion. (See Plate XVII.)

Even before the results of the publicity campaign were beginning to come in, Dr. Hoffman reported another infestation on causarina and citrus, west of Dorado, ten or twelve miles in an airline from San Juan and seven or eight miles west of Isabela Grove. At first this seemed to be an isolated outbreak, but later and more careful observations in this region disclosed an infestation in a few citrus trees just outside of Dorado. That only two infestations were discovered in this region is largely due to the scarcity of appropriate hosts, most of this region being in cane, pasture or coconuts. Their presence, however, and the complete absence of infestation east of San Juan, despite an abundance of suitable hosts, confirms the original observations on the importance of the prevailing wind as an agent in dispersion.

Farther west of Dorado than Dorado is west from San Juan, a small infestation was much later discovered on a windbreak of casuarinas in the hills back of Barceloneta, on the Florida road. This might have resulted from the scale being carried on an automobile, for the casuarinas were close to the main road into the grove, but it seems more likely that this infestation represents another chance wind infestation, a jump of at least twenty miles from the nearest other known infestation. #

Just as the prevailing wind is the most important factor in natural dispersion of the cottony cushion scale, so humidity is the most important factor determining abundance. The north coast of Puerto Rico, where all known infestations of cottony cushion scale occur, has an annual rainfall of from 50 to 90 inches. The distribution of the rainfall is by no means uniform thruout the year, and in general the late winter and the spring months are the dryest. The cottony cushion scale has unquestionably been present for several years in Puerto Rico, but it appeared in noticeable and distinctive

This infestation is now (October, 1933) known to have been of Icerya montserratensis, N O T the Australian cottony cushion scale.

abundance only during the exceptionally dry spring of 1932. As the spring advanced, new infestations were discovered every few days, and despite a strenuous campaign of spraying and pruning, new areas of even denser infestation were constantly appearing in unsprayed parts of groves. The limited numbers of the Australian lady-beetles that could be released seemed quite unable to make an impression in the unsprayed areas where they had been released. During February, March and the first three weeks in April, 1932, less than an inch of rain per month fell anywhere in the infested area, and it was towards the end of this prolonged drought that the scales became most numerous.

The situation changed in May, 1932, when the average rainfall for the region was nearly 13 inches, and during June, July and August, averaged over 7 inches per month. For periods of four or five days at a time, rainfall would be almost continuous, and humidity would remain high, even when rain was not actually falling. Temperatures were also high during most of this period, not only during the day but all night long. It was a most uncomfortably hot and humid summer for people living in and near San Juan, and it was deadly for the cottony cushion scale. In citrus groves well protected by windbreaks, humidity remained high at all times, and, fortunately for the growers, most of the infestations were in windbreak-protected blocks. Isabela Grove, despite its proximity to the ocean, is exceptionally well protected, for the citrus trees were originally planted in clearings thru primeaval forest, and this natural windbreak has been constantly reinforced since. When the grove was examined in July, not a single live scale could be found. When one considers that thousands of trees in this extensive property had been infested only two and a half months previously, and new outbreaks were constantly being discovered on unsprayed trees so fast than all the spraying equipment available could not treat them, the contrast was amazing. A few lady-beetles had been released in this grove, but not a trace of them could be found in July, and their presence at any time could have been only a very minor factor in the elimination of the scale. Practically all of the infestations were found covered with a greyish-white fungus, never before observed in Puerto Rico. Thru the courtesy of Miss Vera K. Charles, this fungus was identified as *Spicaria* sp, and Mr. E. West of the Florida Station states that it is identical with what they call *Spicaria javanica*.

Very heavy infestations of limited extent on citrus trees in pockets in the hills around Bayamón showed even more beautiful examples

of complete and very recent destruction of the scales by this fungus. Its distribution was not extensive at first, however, and on one scale infestation discovered at this time on a citrus grove in Pueblo Viejo which had shortly previously been sprayed with Bordeaux, none of the fungus was to be observed. The owner brought leaves and twigs covered with fungus-killed scale from Isabela Grove, and placed them in one tree, otherwise untreated, between others which he sprayed with kerosene emulsion. Two weeks later, all the scale had been killed on the tree where the fungus had been introduced, while many scales were still alive on the sprayed trees. Naturally the owner was enthusiastic about the value of the fungus, and he was rapidly placing leaves with fungus-killed scale in all parts of his grove. Fortunately for the success of his experiment, humidity remained high for several weeks thereafter, and when examined a month later, not a single live scale could be found in his grove. Another report of scale infestation, which could not be examined immediately, was later found to have been completely eliminated by the fungus.

Continuously high humidity for several days is absolutely essential for the successful use of *Spicaria*. This was abundantly demonstrated in one grove where the scale infestation extended from a knoll-protected hollow to the top of a wind-swept hill. Within a few weeks, not a scale was to be found in the hollow, but as one went up the hill, infestations increased in intensity. The citrus grove at Dorado was very imperfectly protected from the wind, and here the fungus never appeared. Its requirements of humidity are more exacting than of a similar entomogenous fungus, *Cephalosporium lecanii,* which in the nursery at Dorado killed many hemispherical scales, *Saisettia hemispherica* Targioni, and green scales, *Coccus viridis* Green, on young seedlings also infested with cottony cushion scale. Experimentally, smears of its spores rubbed on scales on casuarina trees by Dr. Mel. T. Cook, of this Station, gave entirely negative results in control. Apparently casuarina trees, generally planted as windbreaks, retain with their needle-like leaves too little humidity on themselves to permit of this fungus being of much value for killing scales on them. Temperature is not so important, for even at minimum winter (tropical) temperatures, *Spicaria* is at least partially effective, as was later indicated in a grove at Bayamón, observed in January 1933, with many freshly killed scales.

The entomogenous fungus, *Spicaria javanica,* is by far the most important factor in control of cottony cushion scale during rainy weather and under generally humid conditions. It is, however, not the only agency attacking the scale in addition to the introduced

lady-beetles. Mention has already been made, in Dr. Leonard's MS report, of the discovery of Phorid flies attacking and developing within mature scales, and his tentative determination of these flies was later confirmed by Messrs. C. T. Green and J. R. Malloch as *Syneura cocciphila* Coquillet.

"The next most important natural enemy in Puerto Rico is the lace-wing fly, *Chrysopa collaris* Schneider. The trash-carrying larvae were usually found feeding in colonies of the scale, often commonly so, and a number of adults were reared. The pupal period occupied only 5 or 6 days.

"The common lady-beetle, *Cycloneda sanguinea* L., was frequently found feeding both as adult and larvae on the scales and the larva of a moth, undoubtedly *Ereuntis minuscula* Wlsm. was several times observed making heavy inroads where the scales were thickly encrusting twigs or small branches."(**7**)

Even more interesting was the discovery by the junior author who was handling all the rearing work of the lady-beetles, that among the scales brought in from Dorado as food for them, a few much smaller lady-beetle larvae were already present. They pupated when less than half the size of *Rodolia* larvae, the adults emerging being small, light red beetles, quite different from *Rodolia cardinalis* in size and color markings, and indeed differing from anything in the Station collection. They were entirely light red in color, except for black eyes, a black spot on each elytron, and a black margin at the base of the elytra and extending for a short distance along the sutural margin. The first specimens reared were sent to Washington for determination and Dr. Chapin replied that they were a new species. Later, additional immature material was collected at Dorado, which, together with other adults, was sent to the National Museum, where technical descriptions have been prepared by Drs. Chapin and Böving (**8** and **9**), the insect being named *Decadiomus pictus* Chapin.

A minute wasp parasite, *Cheiloneurus pulvinariae* Dozier, as determined by Mr. C. F. W. Meusebeck, was reared from cottony cushion scale by the junior writer in May, 1932. This parasite was originally described by Dr. Dozier from material reared from a soft scale of sugar-cane, *Pulvinaria icerya* Newstead, but which he considered as being "a hyperparasite on the primary parasite of this scale, *Aphycus flavus*, with which it is always reared."(**10**)

The original host in Puerto Rico of both this and the other recently discovered insects predaceous and parasitic on cottony cushion scale is the not very common native cottony scale, *Icerya montserra-*

tensis R. & H. The larvae and adults of *Rodolia* will also feed on this native scale, at least in captivity and indeed a few of them have been reared on this scale when a sufficient supply of the Australian species was not available. The Phorid fly, *Syneura cocciphila* was originally, according to a letter from Dr. Aldrich, "collected from *Icerya purchasi* at Victoria, Mexico, October 16, 1894; Magdalena, Sonora, Mexico, September 26, 1894; Tamaulipas, Mexico, November 30, 1894. These are records from the type material. Other specimens (in the National Museum collection) are from Sao Paulo, Brazil, collected by A. Hempel, January 1899, from *Icerya brasiliensis.*" To this is now added the rearing record from the native scale. One parasite which has been reared only from the native scale is a small yellow Braconid wasp, of which the antennae, eyes and wing veins are black, determined by Mr. C. F. W. Muesebeck as *Rhyssalus brunneiventris* Ashmead.

The high humidity of the late spring and early summer of 1932 was not only highly destructive of cottony cushion scale, but it also made the artificial rearing of the predaceous *Rodolia* lady-beetles extremely difficult. In all discussion of the rearing work, it must be kept in mind that no infestation of cottony cushion scale occurs within several miles of the Experiment Station at Río Piedras, and it was not considered a desirable policy to establish colonies there in the open, while facilities for rearing large supplies of food for the lady-beetles were not available under cover. Consequently, scales had to be brought in from elsewhere to feed the beetles, and often most of the scales collected at this time were either dead or dying from fungus attack, or became infected immediately they were brought to the insectary. In this emergency, the casuarina hedge in the patio of the School of Tropical Medicine, where Dr. Hoffman had first observed the scale, and where it was still abundant, proved of great value in keeping a supply of the beetles alive. Only a few pairs were released there originally, but they throve to such an extent that their progeny soon spread to adjacent scale-infested casuarina trees of the grounds around the U. S. Army barracks. By the middle of September, hundreds of pupae could be collected here, and releases of beetles were made in all citrus groves where infestations of the scale still existed. The combination of fungus in windbreak protected groves, with ladybeetles in those where protection from the wind was less perfect, had by the middle of September 1932, reduced infestations in citrus groves to insignificant numbers. Indeed, it was rapidly becoming difficult to find places where beetles could be released to advantage, for the supply of food in sight for them was

so limited. Had such conditions continued for only a short period longer, absolute extermination, which seemed so visionary six months previous, might have become a fact.

In certain groves, the destruction of cottony cushion scale by *Spicaria javanica*, not only approached, but actually was 100 per cent perfect. If such conditions had been general, the problem would have been solved. In reality, however, certain parts of infested groves were so poorly protected by windbreaks that the fungus had little effect, and on the casuarina trees and hedges of San Juan and Santurce, none at all. In a very few cases the *Rodolia* beetles destroyed every scale insect present, but in most cases a few scales would be found even where beetles were repeatedly released. It was apparent that there was not enough food present to feed many lady-beetles or their larvae, but they usually failed to eat up even that little. Where only a few scales were left on a small tree, these could be destroyed by hand-picking; but to care for other infestations on larger hosts, or widely scattered in a grove, some other means must be used. The statement of Prof. Essig regarding the relative efficiency of the Agromyzid fly, *Cryptochaetum iceryae*, and *Rodolia* (already quoted), was so unequivocal that it seemed desirable to attempt the introduction of this parasite into Puerto Rico, and see if it would clean up what the beetles left. Mr. S. A. Rohwer, Acting Chief of the U. S. Bureau of Entomology, referred the request for a shipment of these flies to Dr. Stanley E. Flanders of the Citrus Experiment Station, Riverside, California, for favorable action.

This was the picture in the latter part of September, 1932: cottony cushion scale absolutely eliminated in some groves where it had previously been very abundant, and greatly reduced everywhere else thru the activities of the lady-beetles, of which an over-abundant supply was available for release and distribution. Even had the beetles failed, we knew what spray would give greatest effectiveness in control under local conditions, and an adequate sprayer and a trained spraying crew was available for any emergency. In addition, a shipment of the Agromyzid parasite, *Crytochaetum iceryae*, was confidently expected in the near future. To be sure the distribution of the scale was quite extensive, but the situation was entirely under control and only time and a continuance of well organized activities were needed to successfully complete the campaign.

During the night of September 26–27, 1932, the hurricane of San Ciprián swept the northern coast of Puerto Rico and entirely changed the status of the cottony cushion scale. As was reported by the senior writer immediately afterwards, the hurricane had but little ef-

fect on soil insects, or on those living where they were well protected against its onslaught, but scale insects of all kinds suffered greatly. "The trunks and branches of trees exposed to the full force of the wind are smoothed of rough bark and all projections in a most surprising manner. Of course some scales persist in the crotches and on the petioles of leaves, but the breaking off of leaves, twigs and larger branches causes an immediate decrease in their numbers only exceeded by the mortality caused by the direct action of the wind and rain in rubbing the insects from their host."(**11**) Not only such large, fluffy and easily dislodged scales as *Icerya purchasi* were blown off of their host, but those with a tough, hard scale, closely appressed to the host, were also carried away. It was the rule, and not the exception, that 95 to 99 per cent of all the purple scales, *Lepidosaphes beckii* Newman, on citrus trees in the region affected by the hurricane, were removed overnight. In the next few weeks after the hurricane, no sign of cottony cushion scale could be found, even on hosts known to have been infested before the hurricane. Of course not every egg and every crawler had been destroyed, but it was a matter of months before the few surviving individuals could be found.

So far as can be determined from observations made in the following six months, the hurricane did not extend the distribution of the scale at all. No new infestations have been found since the hurricane, and apparently its actual effect it to destroy all those blown off the host, and not to carry them uninjured to a new host, miles away. The force of the hurricane wind is too great, and is destructive, rather than dispersive, of these soft, fluffy insects.

Just a month after the hurricane, a shipment of scales heavily infested with *Cryptochaetum iceryae* was received. This shipment was mailed at Riverside, California on October 18th, 1932, and was delivered at the Station in Río Piedras on the 25th, having been sent by air-plane mail. Thirty flies had already emerged en route, and these were released on the date of receipt in two, protected casuarina hedges in Santurce where a very few large cottony cushion scales had survived the hurricane. For the next weeks, releases were made of twenty or thirty flies every other day in every place where scales were known to have been present before the hurricane, even tho none could be found at the time of release of the parasite. A few weeks later, when scales were more apparent, daily hand collection was organized in San Juan and Santurce, but not a fly emerged from any of this material collected where the releases had been made. Nor were any flies reared from scales collected in citrus groves where releases had been made, and it appears probable that the introduction

was a failure, largely because the sending was received at a time when so few scales were available to be parasitized.

This imported Agromyzid fly was not the only insect dependant on cottony cushion scale, of which greater numbers were present immediately after the hurricane than could be fed. Because of lack of food for them, or any means of obtaining it, all the live *Rodolia* beetles at the Station had to be released in a citrus grove in Bayamón which before the hurricane represented the heaviest infestation of scale known at that time. Besides these beetles in captivity, some in the open also survived the hurricane. That casuarina hedge in the patio of the School of Tropical Medicine, on which Dr. Hoffman had first observed the scale on this host, and on which *Rodolia* was breeding at the time of the hurricane, was so well protected against the force of the wind by the three story building of the school as to be practically undisturbed. On October 6th, ten days after the hurricane, about thirty fresh (unemerged) beetle pupae were noted on this hedge. They were not collected for release of the beetles elsewhere, for scanty as was the prospective supply of food for them on this hedge, just then it represented more of large scales than was present is all the rest of Puerto Rico. These few *Rodolia* beetles were all that survived the hurricane, and practically all of their progeny perished soon after from lack of food.

So far as is known, *Rodolia* beetles survived the post-hurricane scarcity of food in only one place. In January 1933, a single beetle was noted by Mr. Richard Faxon on some scale infested pigeon pea bushes growing across the street from his office in the Ochoa Building, possibly a mile to the west of the School of Tropical Medicine. In the next few weeks, a number of fresh (unemerged) pupae were collected here, to form the nucleus of renewed breeding operations at the Station.

Thru the courtesy of Dr. C. L. Marlatt, Chief of the Bureau of Entomology, a shipment of *Rodolia* beetles was received from the Cottony Cushion Scale Laboratory of the Bureau, at New Orleans, being mailed there by Mr. A. W. Cressman on February 7th, 1933, and received at the Station in Río Piedras on the morning of the 11th. This shipment contained 35 pupae when it left New Orleans, several of which transformed to adult en route, and all arrived alive and vigorous. Combined with the few beetles collected from the pigeon pea bushes opposite the Ochoa Building, this shipment gave the Station an ample supply for breeding, so that hundreds of beetles were ready for release by the middle of the spring of 1933.

The hurricane of San Ciprián unuestionably destroyed 99 per cent or more of all the cottony cushion scale alive in Puerto Rico on September 26, 1932, and for the first few weeks afterwards, no scale could be found. But a few individuals had survived, and in the succeeding months they were able to reproduce more rapidly than before because the hurricane had even more completely swept away their natural enemies, even including windbreaks. At first it seemed as tho it might be possible to destroy these few survivors, and a careful and intensive search was made in every place where the scale was known previously to have been present, and every individual discovered was collected or destroyed by hand. Young scales were found in various protected locations on the host, between petioles and twig, in crotches, and in greatest numbers at the edge of the callus growing over the wound where a branch had been sawed off. An obvious clue to their discovery on citrus trees was a line of the fire ant or "hormiga brava", *Solenopsis geminata* F., which had promptly adopted this Australian immigrant, and entered into even more active symbiosis with it than with most native soft scales and mealybugs. As a general rule, citrus trees with no ants are free from "honey-dew" producing mealybugs or soft scales. Where ants were present, young colonies of cottony cushion scale (or some other soft scale, or mealybug) were almost invariably present also. The hurricane had doubtless destroyed much of the usual food of the fire ant, and they were in consequence especially solicitous to preserve and care for any insect able to provide them with "honey-dew". In numerous cases they were observed to have built a structure of carton and earth over young colonies of cottony cushion scale located on callus margins of wounds, such structures being reminiscent of hurricane sheds, or "tormenteras", altho all were constructed after the hurricane, rather than before. Gradually, as the citrus trees put out new leaves, the scales began to appear exposed on the new leaves and on twigs, having left their pseudo-tormenteras and no longer receiving such intensive care from the ants.

During the remaining months of 1932, the numbers of the scale increased slowly, but with the beginning of dry weather in the early months of 1933, a very considerable increase in their numbers became apparent. In not a single place had the scale been entirely destroyed, despite constant watchfulness and hand collection. The earlier outbreaks on casuarinas in San Juan and Santurce were controlled by spraying, and by organizing a system of daily hand collections from a few trees which were not sprayed, an adequate supply of food was maintained to rear and have ready for general distribu-

tion hundreds of *Rodolia* beetles early in March. Because such an abundance of the beetles, lacking in 1932, was available and was released this year, no such tremendous increase in abundance of the scale as occurred in the spring of 1932, paralleling the practical absence of rainfall, was to be expected this year. Approximately three thousand beetles were released in March, April and May of 1933, effectually checking all incipient outbreaks and so thoroly cleaning up others as to almost approximate local extermination.

SUMMARY

1. The Cottony Cushion, or Fluted Scale of Australia, *Icerya purchasi* Maskell, is known to have been present on rosebushes in Puerto Rico since early in 1931, and presumably had been present for some time previously.

2. It first appeared in noticeable and destructive abundance on casuarinas (Australian pines) in San Juan and Santurce, and in citrus groves mostly less than ten miles to the west and southwest of San Juan, during the exceptionally dry spring of 1932.

3. Natural dispersion of the scale is by the prevailing north-east winds: from the original focus in San Juan and Santurce to the west and southwest.

4. In the citrus groves well protected by windbreaks, the scale was entirely eliminated by an entomogenous fungus, *Spicaria javanica*, never before recorded from Puerto Rico, which attacked it during the extremely wet weather of May 1932, and persisted during the following humid summer months.

5. The Australian lady beetle, *Rodolia (Novius) cardinalis* Mulsant, brought to Puerto Rico by airplane from Florida and later from New Orleans, is reasonably efficient in cleaning up scale infestations in less humid locations, such as exposed citrus groves, and on casuarinas growing close to the ocean or planted to serve as windbreaks.

6. Of native parasites, the most important is a Phorid fly, *Syneura cocciphila* Coquillet, originally described from Mexico, and never before found in Puerto Rico. The scale is also attacked by a wasp, *Cheiloneurus pulvinariae* Dozier, described from Puerto Rico, and by a small lady-beetle, *Decadiomus pictus* Chapin, a new and previously undescribed species.

7. During dry weather, almost perfect control is obtained by spraying with a standard heavy engine oil-fish oil soap emulsion, of which fusel oil is the stabilizer.

8. Except in special instances where especially well protected by

high buildings, all the large scales and practically all the small scales were carried away and destroyed by the hurricane of San Ciprián, September 26–27, 1932. A few scales in protected locations on their hosts escaped destruction and were later able to increase rapidly in abundance because the hurricane had been even more destructive of their natural enemies.

9. So far as can be determined, the hurricane had no effect in the dispersion of the scale.

LIST OF ILLUSTRATIONS:

PLATE XV

The Cottony Cushion Scale, *Icerya purchasi* Maskell, on Casuarina or Australian Pine, *Casuarina equisetifolia*. Natural Size. (Photograph by Guillermo Rodríguez.)

PLATE XVI

The Cottony Cushion Scale, *Icerya purchasi* Maskell, (left) and a native cottony scale, *Icerya montserratensis* Riley & Howard, (right) on Casuarina or Australian Pine, *Casuarina equisetifolia*. Twice natural size. (Photograph by Guillermo Rodríguez.)

PLATE XVII

The Known Infestations of the Cottony Cushion Scale, *Icerya purchasi* Maskell, in Puerto Rico, before the Hurricane of San Ciprián, September 26–27, 1932:

Smaller cities and towns referred to in the text indicated by circles; infestations by solid black areas. (Original.)

PLATE XVIII

Outline map of Puerto Rico showing by Dots the Extreme Limits of Dispersion of the Cottony Cushion Scale, *Icerya purchasi* Maskell. For details of exact location of infestations, see Pl. XVII. (Original.)

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PLATE XV.

PLATE XVI.

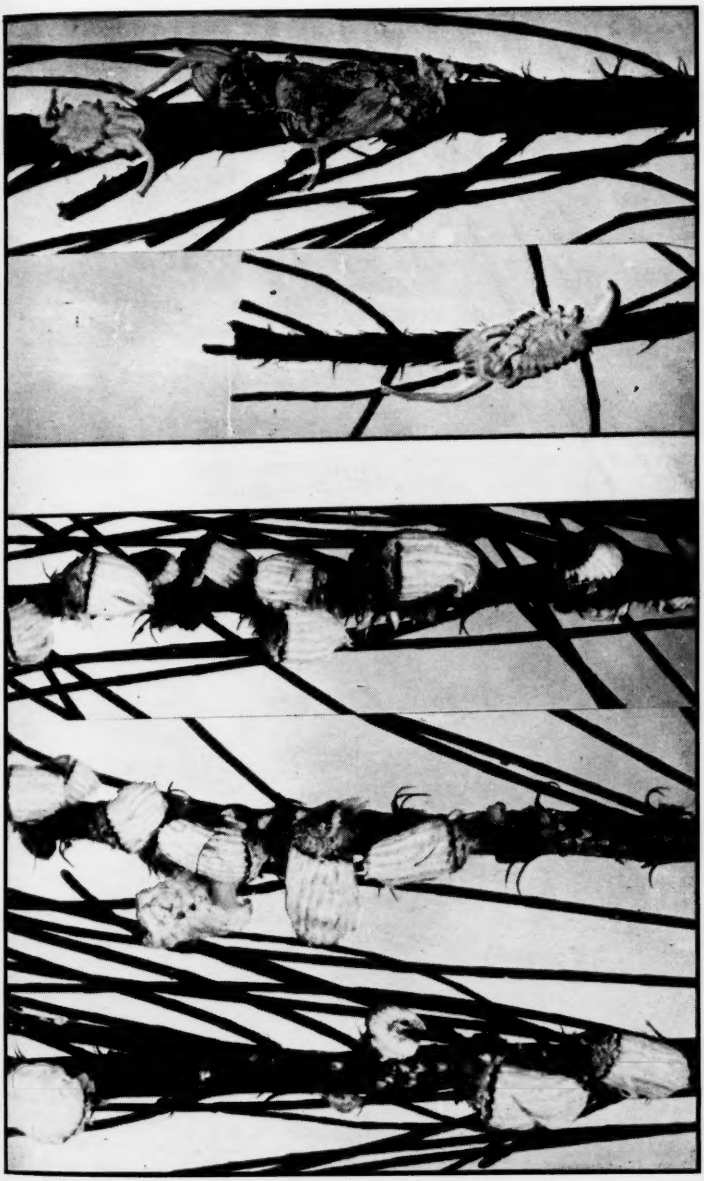


PLATE XVII.

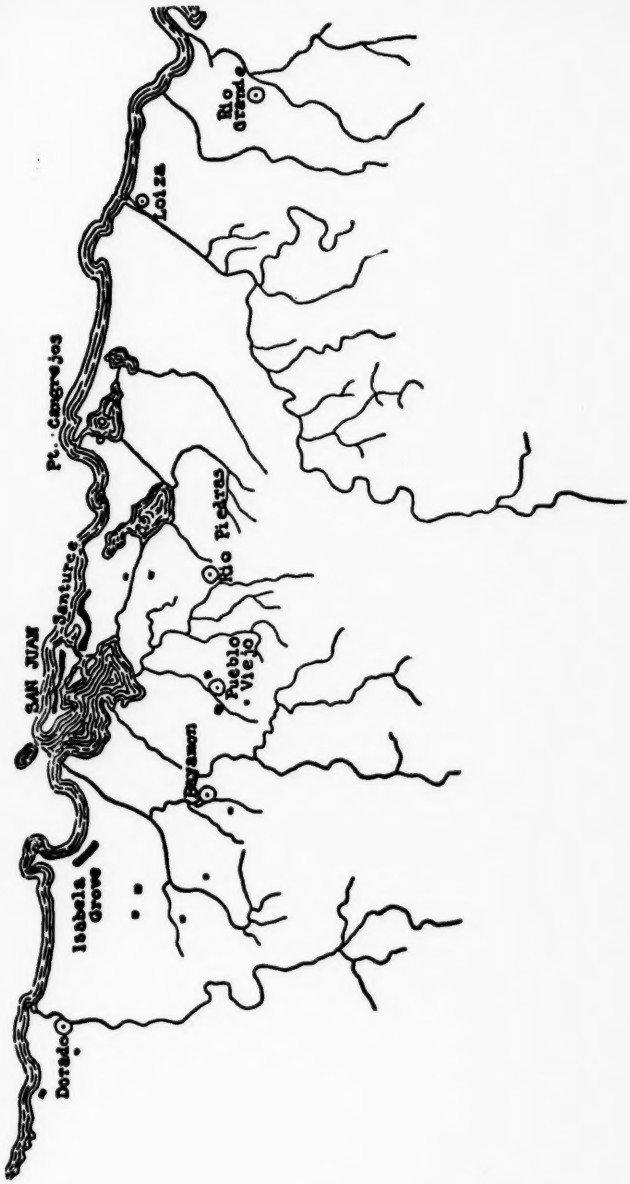
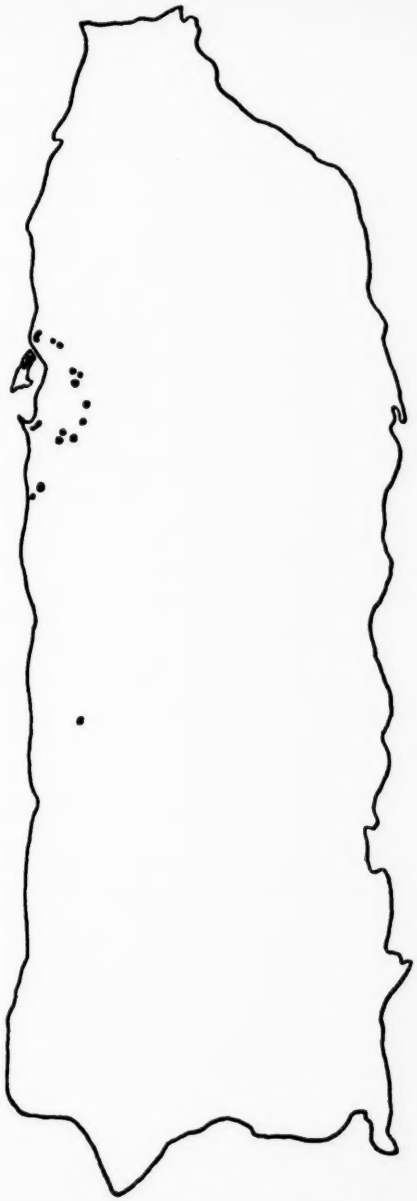

Río Grande
Loiza
Pt. Cangrejos
Río Piedras
Santurce
SAN JUAN
Pueblo Viejo
Bayamon
Isabela Grove
Dorado

PLATE XVIII.



RECENT EXPERIMENTS IN THE CONTROL OF TWO PUERTO RICAN ANTS

By GEORGE N. WOLCOTT, *Entomologist*,
Insular Experiment Station, Río Piedras, P. R.

The control of ants in temperate zones is a comparatively simple matter, for ants there affect man directly mostly as household pests (and to only a minor degree in decreasing crop production), and against them in houses, simple and familiar methods of control have long been in use. As a natural consequence, comparatively little attention has been given to devising any new remedies. When a foreign ant, such as the so-called Argentine Ant, with most injurious habits, and not susceptible to the time-worn and "old reliable" methods of control, does become established, adequate study of its habits and individual preferences eventually shows how it may be controlled (1). A comparable result may be confidently anticipated in the tropics when the importance of the various economic species is recognized and the control of each is considered a separate and distinct problem. To be sure, numerous species of ants are household pests in the tropics, but some of the same, or often quite different species are of much greater importance as factors in affecting crop production. Their habits are often, in the main, similar to those of the ants of temperate zones, but in other cases are so completely different that they are only slightly inconvenienced if the methods of control so successfully used elsewhere against other species are tried out against them. Even, and in many cases especially, the Argentine Ant syrup—devised for use against this one ant and against no other—is a failure. The fundamental difficulty is that the most diverse of tropical ants are lumped together as one kind of insect, against which one standardized method of control should be effective. As a matter of fact, they are as different and individual in their habits as tho they belonged to different orders of insects. In Puerto Rico, the country people speak of and recognize several kinds of ants, and most of them know at least the following:

1. "albaricoque", *Tapinoma melanocephala* F.
2. "albayalde", *Wasmannia auropunctata* Roger.
3. "barraco", *Odontomachus haematodes* L.
4. "hormiga brava", *Solenopsis geminata* F.
5. "hormiga loca", *Prenolepsis longicornis* Latreille.
6. "hormiguilla", *Myrmelachista ambigua ramulorum* Wheeler.

To be sure, this is hardly more than a tenth of the total number of kinds of ants found here by Dr. Wheeler (**2**), but it includes all the common and distinctive species. That so many can be distinguished by an ordinary person is the surest indication that in their activities, or some other factor affecting man, they are essentially and fundamentally different.

Of all the species of ants present in Puerto Rico, the fire ant or "hormiga brava" is by far the most abundant generally, and affects man in the most varied ways. It is a pest in citrus groves and in pineapple plantations, and as these crops earliest received attention at the newly organized Agricultural Experiment Station at Mayagüez, the first economic study of the hormiga brava in Puerto Rico was conducted there (**3**). The slender circular (undated and with not even the place of publication noted) detailing the results of these studies has long been out of print. Because the method of control there given is today just as effective and practical as when first devised, it is here reprinted without change. It should be noted, however, that the common mealybug of pineapples, in Puerto Rico as elsewhere, is *Pseudococcus brevipes* Cockerell.

PORTO RICO AGRICULTURAL EXPERIMENT STATION

D. W. MAY, *Special Agent in Charge*

CIRCULAR No. 7

CONTROL OF THE BROWN ANT
(*Solenopsis geminata, Fab.*)
and the
MEALY BUG
(*Pseudococcus citri, Risso*)

IN PINEAPPLE PLANTATIONS

The brown ant and the mealy bug are at present doing considerable damage to pineapples. The brown ant alone seldom does any real damage; it is when it accompanies the mealy bug that the destructive work begins.

These ants are always found where mealy bugs are present, not eating the plants themselves, but attending the mealy bugs, carrying them from place to place, distributing them over the new leaves, and, as a reward for their labor, obtaining the honey dew which is secreted by the mealy bug. A few cases have been observed where the mealy bugs were so numerous that they irritated the fruit to such an extent that the juice began to run. This was eaten by the ants and they then continued to eat into the fruit, puncturing it and getting more of the juice. Some of these fruits were packed and shipped to New York, while others were kept at the Station. The fruits shipped to New York broke down and were unsalable. On examining a number of fruits after ten days, which is equal to the time elapsed in shipping, it was found that a fungus had gained entrance through these minute holes, causing the pines to break down.

LOCATION OF ANTS' NESTS

Ants generally attack the outer rows of plants first, gradually working in towards the center of the patch. The outer rows and borders of a pineapple field should be carefully watched and all ant hills destroyed as soon as found.

The nests of the brown ant are found in almost any part of the pineapple plantation; around the base of the plants, under the roots between the rows and in the paths, but more often they are found around the roots of the plant. When the nest is under the plant, the ants often carry sand and earth up into the plants and build other nests in leaf axils.

Upon examining these nests a great many mealy bugs are to be found. These are tended by the ants and distributed by them over the young leaves, and from plant to plant.

Before the flower stalk develops, the mealy bugs are found on the leaves around the center of the plant, especially between young leaves which are very close together, as these afford better protection for the insect. On fruiting plants, the mealy bugs are found on the flower stalk, also around the base of the fruit, and very often on the fruit itself.

NOTES ON SPRAYING

Kerosene emulsion, with a small amount of crude carbolic acid has given the most satisfactory results in killing the mealy bugs and the ants. Extensive tests with crude oil sprays have been made but none of these emulsions have proved as effective in killing the ants and mealy bugs as emulsions made with a low grade of kerosene oil and crude carbolic acid.

Formula for Spraying Pineapples.

2 gallons of kerosene
1 pint of crude carbolic acid
½ pound Fairbank's Blue Cloud Soap, or Good Caustic Potash Soap.
1 gallon of water

First put the oil in a barrel. Then dissolve the soap in the water with the carbolic acid by boiling, and pour into the barrel. Mix the whole with a spray pump by pumping back into the barrel for half an hour. A creamy mixture will be obtained which should hold up for from two to three weeks. This is to be used as a stock emulsion. Use 1 gallon of stock emulsion to 8 gallons of water.

ANTS' NESTS UNDER PLANTS

When there is an ants' nest directly under and around the plant, it is best to spray the nest first. If this is not done, the first drops of spray falling from the plant will startle the ants and they will immediately begin to move out carrying their young with them, and in this way many will escape the spray. When the nest is large, it is suggested that it be sprayed and then broken up with the nozzle forcing the spray down into the nest. In this way few ants have a chance to escape, but, as many of them are away feeding at the time, it is necessary to spray again the next day when the remaining ants will be busy building a new nest. This new nest is built close to the old one. All nests in the paths and between banks should be treated in the above manner.

An extension rod about three feet long is very handy in spraying pines, and an elbow is also advised so that the spray may readily be turned down between the leaves.

There is a time in the life of the pineapple plant when it should not be sprayed, that is, when the fruit bud is forming. At this time the bud is very delicate and any spray which will kill the mealy bug or ant, is liable to injure the bud. The spray does not always kill the blossom, but the fruit may develop without a top or crown. Fruits which have formed and stopped blossoming may be sprayed, but great care should be taken.

As the mealy bug is found between the central or the new leaves of the pine, a nozzle which throws a fine but forcible spray is ideal. The nozzle should not throw a spray which spreads over a great area, but one which can be directed down between the leaves, reaching a depth of eight inches and not spreading over an area of more than four inches. It is not the amount of spray that kills, but the spray that hits the mealy bug with force enough to remove the mealy coat and thus saturate the skin of the insect.

As the heart leaves of a pineapple are very small and lay very close to the next set of leaves, it is recommended that the nozzle be placed against one of the second row of leaves, thus spraying the outside of the heart leaf and the inside of the next leaf at the sale time. There are generally three sets of these leaves which come together in the above manner. It may seem impracticable to spray in this way, but, if the nozzle is not inserted between the heart leaves, the mealy bug will not be killed. To spray in this way takes a little longer than filling the crown, but after one has become accustomed to the work, it can be done very quickly.

When pines are sprayed in this manner the emulsion runs down over the central portion of the plant, filling up the crown and gradually running down around the roots.

W. V. TOWER,
Entomologist.

Mr. Tower, continuing his observation on the hormiga brava as it affected citrus growing (**4**), states that on fruits, "the scars made by ants are altogether different from those produced by the wind, the former being deep-seated and caused by the insects removing some of the epidermis and eating into the fruit.

"There are several species of ants which feed upon the nectar secreted by the orange blossoms. The brown ant and the little black ant are especially fond of the nectar. These two species have been seen working in the blossoms in the early morning, sipping the nectar, and toward noon, when it has been exhausted, attacking the unopened blossoms, or young fruit. Some cases have been observed where the green calyx leaves were eaten so badly that the fruit dropped. In other cases the pistil was chewed off and the fruit never developed. Again, the brown ant sometimes cuts holes in the young fruit.

"Ants do more damage during years when there is scanty bloom or when the bloom extends over a prolonged period, as they eat the fruit when not supplied with sufficient nectar.

"Ants are always found where the white fly and the Lecanium scale are present. They attend these two insects to obtain the honeydew secreted by them. When their supply of food is suddenly cut off, ants often attack the young, tender shoots of the orange, eating them at the point where they join the branches. They also eat young, tender leaves, and a few cases have been observed where they had cut holes in ripe fruit. Under these conditions much damage is done. They also carry sand up around the base of the trees, and when there is scant food supply they gnaw the bark of the tree where it is covered by their sand houses. Often when pineapples have been removed from between rows of orange trees ants attack the latter in great numbers, scarring the trees, eating young, tender shoots and cutting holes in the fruit.

"When they appear in this way they must be killed by spraying. The simplest and most inexpensive spray that has been used is carbolic acid soap. The following formula has been used with great success:

Water	1 quart
Soap (Good's caustic potash or whale-oil, or Fairbank's blue-cloud soap)	½ pound
Crude Carbolic Acid, 100 per cent (dark)	1 pint

"Dissolve the soap in water and add the crude carbolic acid, then add sufficient water to make two quarts. This should be used as a stock solution, using one pint of the stock to six gallons of water.

"In spraying for ants it is advisable to locate the nests and destroy the ants by spraying down into them. A second spraying is always necessary the following day, as many of the ants are away from their nests at the first spraying. In spraying large nests it is a good plan to first spray a circle around the nest and then to spray directly into it, thus making it impossible for the ants to crawl out and insuring their being killed by the emulsion."

In the following years, when the Yothers formula for making the "cold-stirred" engine oil emulsion had been generally adopted by citrus growers for the control of scale, it was found that by adding a small amount of crude carbolic acid (one pint to 25 or 50 gallons of spray, or one-half to one-quarter of 1 per cent), this oil spray could be made also toxic to ants, and for an extended period would protect the trees sprayed with it from ant attack. Numerous growers, especially those in whose groves ants were especially troublesome, came to add the crude carbolic acid as a routine practise. It must be admitted that its use was not exactly popular, for its effect is to

quickly rot the rubber gaskets and other rubber parts of the spraying apparatus coming in direct contact with the spray. In other respects, however, crude carbolic acid meets every requirement, for it is cheap, easy to apply and unquestionably effective in killing ants. In the case of many insecticides, a purer or finer (and more expensive) grade of poison is necessary if injury to the plant is to be avoided, but in the case of carbolic acid, the effectiveness resides largely in crudities present with the acid. Consequently, the dark, unpurified and cheapest grades (containing the smallest amounts of carbolic acid) are the most desirable for insecticidal purposes.

A little later, when commercial manufacturers began placing oil emulsions or "miscible oils" on the market which were equally effective in killing scale, and much easier to use because they need only to be diluted with water, many growers ceased to make up their own sprays and relied entirely on the commercial product. Some of these contained some crude carbolic acid, added by the manufacturer for ease in making the emulsion and not for any insecticidal value the substance might have, but others contained none. No stress was laid on whether the product did, or did not, contain enough crude carbolic acid to kill ants, and in general, most growers did not consider this factor in making their selection from the numerous products recommended primarily (and usually solely) for killing scales. Of course, most groves on the Island are mature and established now, and suffer less noticeable ant injury; but in nurseries and young groves ants are no less abundant or injurious than they have been formerly, and the need for a means of control is just as great as ever. Theoretically, the problem of control of hormiga brava by means of crude carbolic acid emulsion is solved; practically, from the standpoint of large growers who no longer make up their own spray concentrates, it is not.

Of the poisons which have come into more general use since the war, the one which has been used with the greatest success in ant control is thallium sulfate. Considerable newspaper publicity at the time was given to successful demonstrations in destroying ants by means of a thallium syrup, conducted in the White House by Dr. R. T. Cotton, formerly of this Station. He furnished a small amount of this expensive and most virulent poison for conducting experiments in the control of the hormiga brava in Puerto Rico. His methods (**5**) were followed exactly at first, using the formula of one-fourteenth of an ounce of thallium sulfate dissolved by boiling in a pint of water, to which is added a pound of sugar and three ounces of honey. A trial was made of the paraffined pill boxes which he

had found useful as containers for the syrup. These containers serve reasonably well in houses, if not disturbed by children, pets or servants, but out-of-doors in citrus groves, they quickly go to pieces. The experiments were continued with paraffined paper cups, all of one piece of tougher paper, over which a cap fits, manufactured especially for this purpuse by the Antrol Laboratories of Los Angeles. Such cups were used in all later experiments and were much more satisfactory. The experiments were conducted in the small citrus grove back of the Sub-Station building at Isabela, and in lawns and flower gardens near-by. In all cases, the ants appeared to feed on the syrup at first, but so far as one could judge, were but little affected by it, and soon learned to avoid it entirely. The results were uniformly discouraging, for in no case was even a small colony of ants completely destroyed, and no apparent impression was made on larger colonies. If the cup was placed at the entrance of the nest, the ants constructed a new entrance several feet away. If a fresh cup was placed at the new entrance, this also was deserted. One large colony in a lawn constructed six new entrances thus in succession, and while some of the ants may have been killed by the poison, no permanent reduction in their numbers was observable. If the cup was placed at the base of a citrus tree, where the ants were ascending and descending, they soon moved their line of march so as to avoid coming near the cup, and if another cup was placed in the new line of march, this also the ants soon learned to avoid. A final and definite experiment planned in the citrus grove at Isabela, laid out at the time of the experimenter's departure, appeared to be a complete success, when examined about two months later. This apparent success was entirely due, however, to the trees and nests having been sprayed by the mayordomo with crude carbolic acid emulsion a few days previous to examination. He had given up hope of the thallium syrup having any effect, and was determined to save the trees from ant injury by a method of the efficiency of which he had been convinced by demonstration on the main block of trees.

In most marked contrast of the uniform failure of thallium out of doors, the syrup was most unexpectedly successful when used in the house, and has since proved uniformly valuable in every experiment since conducted. A cup of syrup placed on the line of march of ants going from their nest to a garbage pail, food safe, bread box or refrigerator, will, within a few hours, eliminate them entirely from their chosen food, and in less than a day they will cease to visit the cup of poison syrup. Weeks later they may again return, but putting the cup out again on the line of march will disperse them more

quickly than before. The syrup is of no value when placed with or beside the food, but when several feet nearer the nest than the food, works with almost magical effect. Collapsible tubes of this syrup can be purchased locally and can be recommended to housekeepers who are not interested in the home preparation of the poison syrup.

While these experiments were being conducted, reports of the successful use of this poison syrup in the citrus groves of the Río Grande Valley of south Texas were received (**6**), and Mr. C. H. Behse, Jr., of the Gulf States Chemical Co. of Harlingen, Texas, came to Puerto Rico to try out some of the mixtures which had proved so successful in south Texas. His experiments in the citrus groves here were no more successful than those conducted by the writer, and as a result of their failure, he submitted additional mixtures, of varying composition, to be tested here. One of these was his standard dry pellets in a collapsible tube, another the syrup in a tube, a third a combination with dried blood, and a fourth, an unknown mixture, dark in color. All of these were placed at the base and higher up in the crotches of large citrus trees near the beach at Dorado, all trees being heavily infested with hormiga brava. After several weeks, they were replaced with fresh tubes. As the supply of tubes containing the unknown were exhausted, these were replaced with a mixture of thallium acetate and ground meat. In some cases, a possible diminution in the number of ants might be imagined on some of these trees, especially those on which the standard syrup was present, but in no case was it sufficiently marked to be considered as constituting even commercial control. After several months, additional fresh tubes and thallium acetate and meat were placed on the trees, but after the lapse of several more months, no more definite results consequent on the presence of the poison could be observed than before.

As a final conclusion to this poison experiment, to parallel a similar experiment previously conducted with the "hormiguilla", a mixture of Hamburg steak and sodium cyanide was placed at the check trees, which had not previously been treated with any poison. The action of the fresh meat on the cyanide is to cause the immediate liberation of hydrocyanic acid gas, which kills all the ants coming anywhere near the meat. Within a few minutes after application thousands of ants were killed, but some were still running about a few hours later, and when the trees were examined a few weeks later, some of the colonies appeared even larger than before. Before making a fresh application of meat and cyanide, all the loose sand at the base of the trees was brushed away, so that the meat could be placed

in close contact with the base of the tree and no ants descending to their nest could avoid it. Within a few minutes thousands of ants were killed, and by moving the bits of meat about so that they rested beneath runways not at first covered, all the ants in sight were soon killed. Brushing away still more of the sand and exposing some of the ants in the nest, these also were quickly killed by placing the meat in their midst. As an indication of how rapid was the action of the poison when properly applied, the case should be mentioned of one tree which had been densely over-run with hormiga brava tending cottony cushion scale. After a few minutes, it was so completely freed of ants that it could be ascended with safety, without danger of being bitten. Meat unmixed with cyanide is very attractive to hormiga brava, but no case was noted of the ants attempting to eat the poisoned meat. In this respect their action was very different from that of the "hormiguilla", a slow-moving, phlegmatic ant which remains quietly in one place eating the poisoned meat until overcome by the hydrocyanic acid fumes. The action of the cyanide and the meat rapidly destroys the great majority of the foraging workers, but some remain uninjured and unaffected deep in the ground. Thus the colony is greatly weakened, but not exterminated. It is not an especially cheap or simple method of killing ants, but it was some satisfaction to see some dead ants after vainly putting out thallium mixtures for so many months. Indeed, it is no more effective than dusting the nests with calcium cyanide dust, a much simpler method of obtaining the same result: the immediate destruction of the great majority of the ants.

The local agency handling the thallium tubes manufactured by Mr. Behse's company reported one rather considerable sale of them to a citrus grower near Barceloneta. He reported that his experience with them had been most successful, and his grove was visited to determine, if possible, the cause of his success. The tubes had been placed in a young grove after the ground between the trees had been thoroly cultivated in preparation for growing vegetables, and after the young trees had been thoroly sprayed, so that most of them were at least commercially free of scale. It is hardly surprising, therefore that after nine-tenths of the ant nests had been broken up by plowing and cultivation, and the main source of food for the ants (the honey dew from the soft scales on the citrus trees) removed, the few survivors had been destroyed by the poison bait. In every case where all the soft scales on a tree had not been killed by spraying, it was invariably heavily infested with ants, indicating that the successful results claimed for the poison were in reality largely due to starvation.

for maximum effectiveness, and the tree was still somewhat infested at the time the last application was made.

As the experiment was continued, certain refinements of methods were adopted. By smearing the very smallest amount of unpoisoned meat about half an inch above the point where the poisoned meat shelf was to be placed, the ants could be induced to collect there and be overcome by the fumes of poison rising from the shelf beneath. The hydrocyanic acid gas is generated in the greatest quantity in the first few minutes after the cyanide is mixed with the meat, and is most effective the more promptly it can be applied to the tree. It continues to be generated for several days, but in much smaller amounts after the first few hours. If the meat does not dry out, it is effective for a considerable period, and has been observed to kill ants five hours after application. Also, the poisoned meat begins to harden soon after mixing, and the more promptly it can be applied, the more easily it can be shaped into a shelf, and the better it sticks. Thus, during the later experiments, only half a pound of meat and an ounce of poison were mixed at a time, the second half pound being mixed and applied some time later. From one shelf, the dead ants were collected and found to number 2,400. If all the shelves were as favorably located, and killing with this efficiency, the total number of ants killed on a large tree would be enormous. The ants killed should weigh almost as much as the meat, for their dead bodies pile up on the shelves so as to bulk larger than the shelves themselves, when not blown away by the wind.

This method of killing hormiguilla, despite the enormous numbers of ants killed, does not destroy the colony, and merely reduces the infestation. But their numbers can be so greatly lessened that old guaba and guamá trees which can not readily be removed, may safely be retained in the grove, if repeated applications of poisoned meat are made at intervals of a few days during dry weather. In practise, the use of ground meat and cyanide is too expensive and troublesome, and is not sufficiently effective to be whole-heartedly recommended to coffee growers generally. So far as known, it has never been used commercially, and, indeed the need for any artificial method of destroying the coffee shade tree ant was largely obviated, temporarily at least, by the hurricane of San Felipe, which blew down most of the older and larger shade trees in the coffee groves of the Island.

As the young shade trees grow larger however, they begin to harbor injurious numbers of hormiguilla, and eventually the problem of their economical control will again become pressing. Thus, at the same time that experiments were being conducted with thallium sul-

fate against hormiga brava, parallel ones were started with this substance against the hormiguilla. A guamá tree, well infested with the hormiguilla was found only a short distance from the Sub-Station at Isabela, and preliminary experiments were commenced on it. The sulfate of thallium is very sparingly soluble in water, but it was hoped that a small amount of the finest powder mixed with ground fresh meat might dissolve. Judging by the results of the first experiment, none did so, for no apparent diminution was noted in the size of the colony after several weeks. When the poisoned meat was first placed on the tree, the ants swarmed about in their characteristic manner, devouring it greedily, but picking out and discarding any particle of the poison, minute to us but enormous to the ant, found mixed with meat. As the obvious cause of the failure of this experiment was that the poison was not in solution, a small amount of powder was cooked up with Campbell's mock turtle soup, and boiled until it was a thick paste. The ants were not the least bit deceived by the pseudo-meaty flavor of this mixture, and paid absolutely no attention to it.

Shortly after the ignominious failure of these experiments, Mr. Behse suggested the use of one of the more soluble compounds of thallium, stating that, in his experience, vastly more than the amount of thallium acetate necessary to kill ants would dissolve readily in the amount of liquid present in fresh beef. For his own work he had not even considered this poison as being commercially practical, on account of its cost, but suggested that the small amount necessary for carrying out the preliminary experiments might be obtained from the Ore and Chemical Corp., 40 Rector St., New York City. Eventually, after some delay, for the poison had to be specially ordered and imported from the factory in Germany, an ample amount for experimentation was received thru the courtesy of this company. In the meantime, however, the experimenter had been transferred to Río Piedras, in the near vicinity of which no hormiguilla infested trees are available for conducting experiments. After vainly examining numerous guaba and guamá trees, it was finally decided to use the historic jagüey tree in the Ciales valley near Manatí, for, in the course of the years which had elapsed since the close of the experiments with meat and cyanide on this tree, the colonies of hormiguilla had again become populous.

The first tentative application of a freshly prepared mixture of about a third of a pound of hamburger steak and two or three grams of thallium acetate on the trunk of this jagüey tree was made on August 4, 1932. The ants swarmed out to feed on the meat with

their accustomed eagerness, and apparently were unaware that it had been mixed with a most powerful poison. To test their perception of the presence of the poison, an additional amount was dusted on the level portion of one bit of meat where they were feeding, and even while it was dissolving in the meat juices, the ants continued to eat.

At the time the application was made, the sun was shining brightly, and the trunk of the tree was dry, but a few hours later the sky became overcast, and during the afternoon and following night several showers fell. None was of sufficient size or duration to get more than a part of the trunk of the tree wet, and when examination was made the next day at noon, it was found that one effect of the rain had been to keep the meat from drying out, and many ants were still feeding on it. Some of the bits of meat had been fashioned into shelves, because the experimenter had become accustomed to moulding them into this shape when cyanide was mixed with the meat, and on these shelves, numerous dead ants were to be seen.

The second application of half a pound of steak and five ounces of thallium acetate was made three weeks later on this tree, in many cases on top of the dry remains of the meat applied previously, but also further around its enormous trunk. The ants came to the meat eagerly, but not in such large numbers on the part of the tree previously treated. A third application was made between two and three weeks later, ants still being numerous on all parts of the trunk. Ten days later a fourth application was made, and it was then for the first time noted that the ants were not especially numerous, and seemed not especially eager to eat the meat. The hurricane of San Ciprián occurred on September 26–27, 1932, and no opportunity to visit the jagüey tree was available until October 20th. Some of the larger branches of the tree, amounting to possibly a third or a fourth of its bulk, had been broken off by the hurricane, but the trunk was uninjured, and many of the larger branches and small twigs were intact. Very few hormiguilla were to be seen, and even when fresh, unpoisoned meat was placed on the trunk, no ants came to it. The remainder of half a pound of steak was poisoned and applied in the usual manner, mostly in new locations, but this brought out only a few ants. Of course, the hurricane by blowing away so many branches had considerably decreased the ant population of the tree, but this decrease would be only approximately in proportion to the amount of the branches so removed. By comparison with the number of ants present two months previously, a conservative estimate was that

99 per cent of them were gone, and most of this was undoubtedly due to the thallium acetate.

The tree was later examined on November 30th, and while the trunk was still entirely free from ants, a considerable number could be found in the tips of twigs, in the part of the tree most distant from the trunk, where the poison had been applied. That the ants should have thus persisted in the tree indicates the difficult nature of the problem of hormiguilla control, for the ant population of a large tree consists, not of a single large colony, but of a large number of separate colonies, not sharply delimited, but each having communication only with its immediate neighbors. All the needs of the members of these colonies are supplied by resources close at hand, and apparently those inhabiting the twigs have little or no intercourse with those on the trunk. Nevertheless, the experiment indicates that commercial control of the hormiguilla: reducing the number of these ants present on the shade trees to such an extent that they do not overflow to the surrounding coffee trees, is now in sight.

How practical control by means of a proteid mixed with thallium acetate will be, how it will work out in practise in coffee groves, and how long such control will be effective, are points yet to be determined. Experiments were promptly started in coffee groves, but the Station at Río Piedras is most unfortunately located for initiating, continuing and observing such work in coffee groves, and the actual operation has necessarily been turned over to the Agents of the Extension Service who are located in coffee regions.

The three most important factors in determining the adoption of any method of insect control are: (1) non-injuriousness to host, (2) effectiveness, and (3) cost. In thus analyzing the value of the thallium acetate meat bait mixture for hormiguilla control, it should be noted that thallium is poisonous to vegetation as well as to animal life, but in the small amounts used, no effect at all has been noted either on the trees on which it was applied, or on the surrounding vegetation. Effectiveness appears to be close to perfection, altho it is yet much too early to say anything about permanence. The third factor—cost—is unquestionably high in the present stage of development of this method of control, but may be very considerably reduced as cheaper and more desirable substitutes for fresh hamburger steak, and simpler methods of application are devised. The poison itself is admitted expensive, but such minute quantities are needed that it is not the major item in total cost. Indeed, in these experiments, the steak at 18 cents a pound was more

expensive than the thallium that was mixed with it. Thallium sulfate is now extensively used in California and Hawaii in rodent control, and in south Texas in ant control, and it is only a third cheaper than the acetate. The present price of thallium acetate is something under $11 per pound in hundred pound lots, or a little over two cents a gram. Up to the present there has been no commercial demand for it, but if other uses for it are developed, this price may be somewhat reduced. It is quite possible that even smaller amounts per treatment would be effective if the poison could be more thoroly mixed with the bait. A uniform mixture would be ensured by the use of a meat jelly, semisolid at ordinary temperatures, but liquid at the higher temperature at which the solution of the poison is added. By the addition of other substances, the jelly could be given other desirable qualities: greater adhesiveness and less tendency to dry out rapidly after application, or to spoil if not used immediately.

SUMMARY

1. Under local conditions, experiments have indicated little value for thallium compounds and mixtures against the hormiga brava, *Solenopsis geminata* F., out-of-doors. In-doors, the thallium sulfate syrup has been just as uniformly successful as out-of-doors it is a failure. An emulsion of crude carbolic acid, either alone or mixed with kerosene emulsion or the engine oil emulsion sprays used for scale control, is still the cheapest and most effective insecticide to use against this ant in citrus groves, pineapple plantings and vegetable gardens.

2. Against the hormiguilla, *Myrmelachista ambigua ramulorum* Wheeler, a bait consisting of ground meat and thallium acetate is very effective, and gives promise of being adopted commercially when cheaper and simpler methods of application are devised.

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THE LIMA BEAN POD-BORER CATERPILLARS OF PUERTO RICO

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The three species of pod-boring caterpillars which attack lima beans in Puerto Rico constitute the greatest obstacle to the profitable production of this crop. Thus, an economic study of these caterpillars has been one of the main entomological projects at the Isabela Sub-Station ever since lima beans were planted there. Careful and detailed observations were made there on beans planted in the late spring of 1931, to determine the relative abundance of the caterpillars in different varieties of beans. On beans planted in the fall of 1931, comparable observations were made on their relative abundance in fields sprayed with Bordeaux mixture and magnesium arsenate, and in fields that were not sprayed at all. On beans planted in the spring of 1932, observations were made on sprayed and unsprayed beans, and on proximity to alternate hosts of the caterpillars. In an extension of this spraying and alternate host experiment, to which was added treatments with nicotine and pyrethrum, on beans planted late in the fall of 1932, final results have just been obtained. As the net result of these observations and experiments, it can now be definitely stated that no method of control of these pests is known. Indeed, all those suggested as likely to result in at least partial control are found by experiment to be valueless. Before considering the experimental evidence in detail, however, it may be desirable to give a general discussion of the insects, and especially of distinguishing characters of the three species of caterpillars and their habits as affecting the possibility of control by any of the means at present in common use.

The term "pod-borer" refers to the habit of these caterpillars of entering the pod when they are very small, and thereafter feeding entirely within the pod, remaining there thruout their larval existence, and sometimes pupating there. The female moths lay their eggs singly on the flower sprays, and the young caterpillars on hatching feed on any of the floral parts. Many of the buds which drop, some of the flowers which drop without setting pods, and most of the young pods which drop, fall from the vine because they have been more or less injured by the feeding of these small caterpillars. The

initial losses caused by these caterpillars are especially obvious at the beginning of the crop, when the ground under the vines will be strewn with buds, flowers and young pods which have served as food for the young caterpillars.

When the pods get to be a little larger and firmer, however, they do not fall from the vine when one of these caterpillars begins to feed, but are thick enough so that the caterpillar burrows right up inside of the pod. As the caterpillar continues to feed inside, and the pod continues to grow, a callus is formed where the caterpillar burrowed in, effectively closing and entirely concealing the point of entrance. So far as one can see by looking at the outside, the pod is perfect. Yet actually the caterpillar continues to feed inside, sometimes confining its activities to only one bean, altho often it chews into two or even three. While the caterpillar is still actively feeding and growing, ordinarily there is no external indication of its presence, but by the time that it approaches full size, its excrement has begun to rot and show thru the pod walls. Thus the infested pod is ruined from the standpoint of marketing, and is discarded when the beans are being sorted for shipment.

All of these injuries mentioned tend to reduce the total production. Quality is also affected, however, when pods ready for shipment contain small caterpillars, for these caterpillars continue to feed and grow while the beans are en route to market. Even if their presence is not apparent when the green beans are sold, the ultimate consumer preparing the beans for cooking is disgusted to discover that they are wormy, and is prejudiced against buying green lima beans in the pod again. Of course no one individual caterpillar can possibly cause all of these described types of injury, but different individuals of each kind of caterpillar cause each one of all these types of injury.

From the standpoint of extensive distribution and of quarantine restrictions at present in force, *Maruca testulalis* Geyer, a Pyralid-Pyraustinid caterpillar, is of the greatest importance. It is present in Japan and many other regions of the old world, but only in Cuba and Puerto Rico of the new world, and specifically not in the United States. For that reason, since July 1, 1925, no beans in the pod can be exported from the West Indies to the United States, except during the winter, and only under special permit and inspection, thus to a considerable extent limiting production in the West Indies. Incidentally, these restriction have been responsible for an intensive study of this insect in Cuba, where it is the most common pod-boring caterpillar. In Puerto Rico, *Maruca* is of only minor importance,

not because it is less abundant than in Cuba, but because two other species are so much more abundant and cause much heavier losses.

All the general statements made regarding pod-borer caterpillars do not apply exactly to *Maruca*, for the caterpillars after burrowing into the pod, have the habit of keeping an exit open to the outside, thru which to void their excrement. This habit is also of value to the bean grower, for he is thus able to make sure of all infested pods, and eliminate them as culls when green beans are being prepared for shipment for distant markets. Of course it does not lessen the injury caused by the caterpillars, but at least the shipper can be sure that

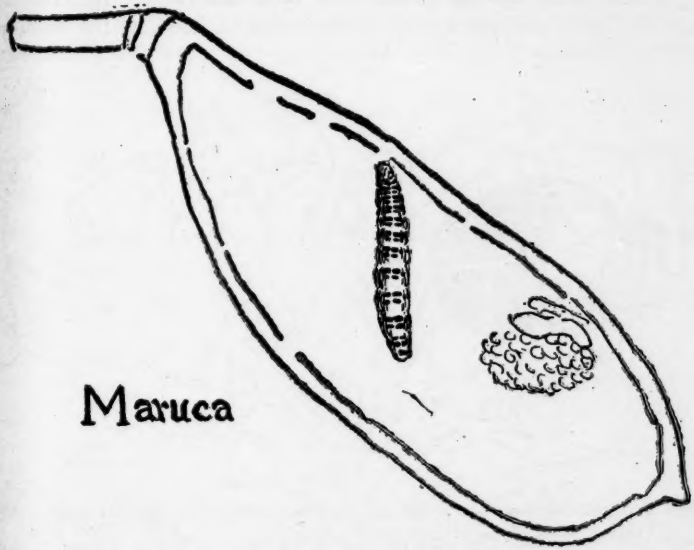

FIG. 1. Caterpillar of *Maruca testulalis* Geyer in small pod in which it has eaten all the beans. About twice natural size. (Original).

he is not sending out infested pods which will rot en route, or arrive in the kitchen of the housewife wormy and disgusting.

Maruca caterpillars are generally of a creamy white, and can most readily be distinguished by their spotted appearance, for they have four large black or dark grey spots on the back of nearly every segment. Sometimes the spots are not very dark, but usually they are quite distinct, and coupled with the presence of a frass-disposal hole to the outside of the pod, one can usually identify the caterpillar without difficulty. When fully grown, the caterpillars are two-thirds

of an inch long, and are then about to leave the pod where they have been feeding. They spin cocoons almost anywhere outside of the pod, or at times, even inside a dry pod, but usually their cocoons are found between pods, or on bean hampers, or in trash on the ground, and only rarely at any great depth in the ground itself. The moth is very active, and when not flying about, stands with wings outspread and all ready to go. The forewings are chocolate brown, with a large white triangular spot on the front margin, and the hind wings are silvery white with a brown spot at the corner more distant from the body.

Parasites of the caterpillar have been reared in Cuba, but are not abundant, and are a very minor factor in checking the numbers

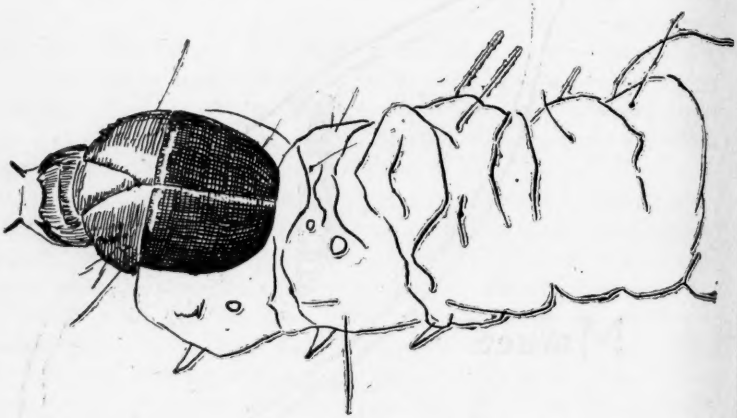

FIG. 2. Head and fore part of body of the caterpillar of *Fundella cistipennis* Dyar. About twenty times natural size. (Original).

of the pest. Spraying with Bordeaux has no effect on the amount of infestation, and about all that growers can do is to hand kill all the caterpillars that crawl out of the pods while they are being packed for shipment, and to destroy the culls. Experiments in Cuba have shown that the caterpillars in the pods can be killed by maintaining the pods for an hour in moist atmosphere of 44° to 46° C., or by fumigating with carbon bisulfid for two or three hours. By such means, wormy beans may be prepared to meet quarantine restrictions, and shipped to northern markets if a temporary scarcity of fresh beans warrants. From the standpoint of maintaining standards, however, a more careful inspection and culling out of all worm-in-

fested pods is much more satisfactory, even tho in special instances it may not be so immediately profitable.

The two more abundant species of pod-boring caterpillars in Puerto Rico are: *Etiella zinckenella* Treitschke (known in California as *E. schisticolor* Zeller) and *Fundella cistipennis* Dyar. Both insects belong to the same sub-family of the Pyralidae: Phycitinae, and in their larval stage are almost indistinguishable. Yet obvious differences do exist, and in Puerto Rico one caterpillar attacks lima beans only during the winter time, when they are being shipped to northern markets, while the other occurs in abundance only during the spring, summer and fall, when no shipments can be made on account of quarantine restrictions, and thus from the standpoint of the export grower is not an economic pest at all. In their earlier

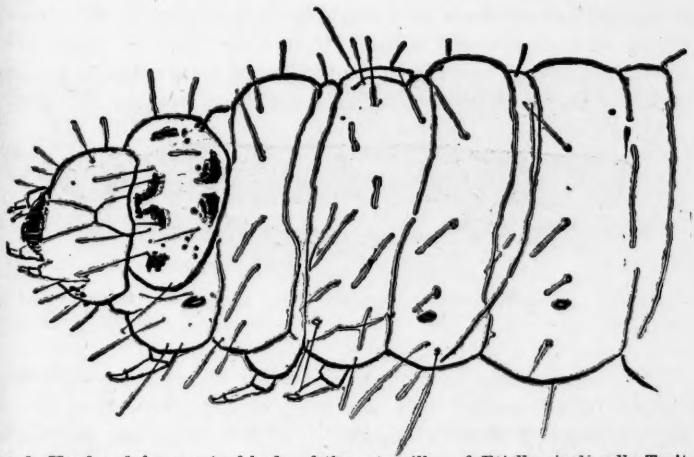

FIG. 3. Head and fore part of body of the caterpillar of *Etiella zinckenella* Treit., showing pattern on thoracic shield. About twenty times natural size. (Original).

instars, the caterpillars are indistinguishable by any gross structure, color or marking, both being light green in color, with a dark brown or black head and thoracic shield. In the last instar, many of the caterpillars as they approach full size become purplish above, altho others (of both species) become more yellowish and creamily opalescent. Both are cylindrical in shape and in size approach *Maruca*, two-thirds of an inch long.

Their heads (in both species) vary in depth of coloration from a light yellow to a dark brown, but the thoracic shield, just back of the

head, furnishes the clue to specific identification. The thoracic shield of *Fundella cistipennis* is of the same color as the head, or possibly a little darker, unmarked, or with the markings scarcely visible because of the dark color of the entire shield, or with the markings distinct but vaguely outlined and of a variable pattern. By contrast, the thoracic shield of *Etiella zinckenella* is invariably opalescent greenish-yellow, marked with a very definite pattern in black; two confluent crescents in the center forward, two broader ones to the rear, and a mark on each side, together with several pairs of small black spots, the four larger anterior marks being in sharply sculptured depressions. This sounds complicated, but, in practise, after one has seen both kinds of caterpillars at the same time and made the comparison, the difference is thereafter unmistakable.

Under normal conditions, the tough, grey cocoons of both species of caterpillars are made at a considerable depth in the soil, those of *Etiella* at a considerably greater depth than those of *Fundella*, but not in hampers or in trash in the surface of the ground as are those of *Maruca*. Adults emerge within a couple of weeks.

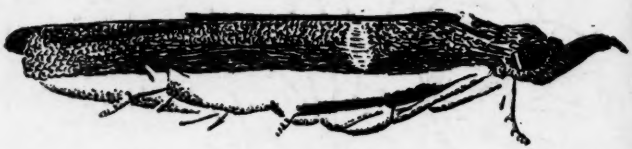

Fig. 4. Moth of *Etiella zinckenella* Treit. About eight times natural size. (Original).

The adult moths of both species when at rest keep their wings tightly folded around their abdomen, very different from the outspread wings of *Maruca*, apparently always just about to fly away. Otherwise than in the manner of holding their wings while at rest, the two species are not similar in appearance, for the forewings of *Etiella* are broadly margined with silvery white, these margins blending with the white of the legs and abdomen when the moth is at rest. Its large palpi stick out like a beak in front. The moth of *Fundella cistipennis* is of a characterless, inconspicuous greyish-brown, with no marked or well-defined pattern on the wings, but with the interesting habit of often keeping the ends of its antennae underneath its folded wings.

As regards other hosts than lima beans, the months show a most surprising difference in those on which they oviposit. During warm weather, *Etiella* caterpillars, somewhat dwarfed and dried-up in ap-

pearance as compared with the plump, juicy larvae occurring in lima beans, and longitudinally striped with purple, are quite common in the pods of *Crotalaria incana,* and in no other species of this genus of plant. Observations on this selection of host plant were made independently by two entomologists in Cuba (L. Dean Christenson & S. C. Bruner), and are confirmed by observations made by the writer in Puerto Rico. On the beach at Mameyes, EVERY mature pod of several bushes of *Crotalaria incana,* observed in mid-summer, was infested. Thruout the year, *Fundella* caterpillars are to be found attacking the pods of sword beans and beach beans, *Canavalia ensiformis* and *C. maritima,* often causing much more obvious external injuries than they do to the pods of lima beans. Sometimes as many as 3 or 4 caterpillars may occur in a single pod. (See plate XIX). (*Maruca* caterpillars are also often found in sword bean pods, their abundance in this host in Puerto Rico considerably

FIG. 5. Moth of *Fundella cistipennis* Dyar. About ten times natural size. (Original).

exceeding that in lima beans). *Fundella* caterpillars also burrow in the stems of cowpeas and attack the young shoots and buds.

The range of these two such similar yet divergent species overlaps only in Puerto Rico, so far as is known. *Fundella cistipennis* was originally described as *Ballovia* from Barbados, and has since been found in St. Vincent, St. Croix, Vieques, Puerto Rico and at Port-au-Prince, Haiti. *Etiella zinckenella* is of cosmopolitan distribution, being reported from many European and Asiatic localities, Colombia in South American, and from many places in the United States, altho it is an economic pest only on the Pacific coast. In the West Indies, it occurs only in Cuba and Puerto Rico.

The reported scarcity of *Etiella zinckenella* on lima beans in Cuba is presumably largely due to the fact that this crop is grown there only for export during the winter. In Puerto Rico, *Etiella* is equally

scarce during most of the shipping season, but in experimental plots of beans planted during the late spring, it becomes very abundant, often attacking from a fourth to a third of all mature pods. During the winter, when lima beans in the pod may legally be shipped to the United States, practically no *Etiella* caterpillars occur, their place being taken by smallers numbers of *Fundella,* and in lima beans grown at the higher elevations, a few *Maruca* caterpillars in addition.

The first counts made of pod-borers at Isabela will serve to indicate the prevalence of *Etiella* in the late spring, altho they were primarily intended to determine the relative infestations of the caterpillars in different varieties of beans. These observations were made in a field planted on Feb. 26, 1931, in which, after the first month, the plants were sprayed every ten days with Bordeaux mixture. The purpose of the planting was to obtain data on yields, but was also available to the writer for examination as to infestation of the pods by caterpillars. The plot was small and samples of each variety of only 25 pods were examined. At the time the examinations were commenced, the characters distinguishing the three kinds of caterpillars were not known, and it is merely presumed that most of the caterpillars observed at first were *Etiella zinckenella,* as all of them were known to be after the first four observations.

PER CENT OF INFESTATION BY POD-BORER CATERPILLARS

Average of the variety	Variety	April 30	May 6	May 16	May 20	May 28	May 30	June 5	June 11	June 12	June 19	July 2	July 20	August 28
12.....	Challenger	8	20	8	16	0	....	....	....	8	24	....	....	....
13.....	Carpentera	12	24	20	12	0	....	....	....	16	8	....	....	....
9.....	Burpee	30	4	4	8	0	....	....	....	....	....	....	....	....
18.....	Fordhook	44	32	16	8	0	....	....	....	....	....	....	....	....
9.....	Average	23	20	12	11	0	3	0	5	12	16	6	15	0

On another field of Challenger pole beans planted at about the same time, at Maleza, near the Agujereada light-house, the infestation by *Etiella* on June 9, 1931 was total, many pods containing two or three caterpillars. By June 30th, it had dropped to 36 per cent infestation, and was 46 per cent on July 20th. In explanation of the great difference in infestation, as compared with the field at Isabela only five or six miles away, it should be stated that infestations are usually very heavy at the beginning of the crop, dropping off rapidly when production is really started.

On the drops from lima beans observed December 1, 1931, in a field of Challenger pole beans at Isabela, sprayed weekly with Bordeaux and magnesium arsenate, the infestation was more than total,

Etiella caterpillars being fifteen times as numerous as *Maruca*, and no *Fundella* caterpillars present. Ten days later, on drops in the same field, most of the caterpillars were *Fundella*, some were *Etiella*, and a few *Maruca* were found. This field did not come into full production until the latter part of December, at which time comparison could be made with two unsprayed fields nearby of the same variety. All of these fields were in commercial production, consequently only cull pods were available for examination.

The cause of rejection varied considerably, being much more numerous in the unsprayed fields on account of spotting by *Elsinoe*, or injury by the leaf-folder caterpillar, *Lamprosema indicata* F., both of which were largely controlled in the sprayed field. Thus the frequency of infestation by pod-borers in the culls from the sprayed field appears much higher, altho it might not vary greatly from the unsprayed fields if the total crop could be sampled. Whenever possible, samples of 100 or 200 pods were examined. The records are given in the following table.

INFESTATION OF POD-BORER CATERPILLARS IN LIMA BEANS GROWN AT ISABELA, WINTER OF 1931-32

Date	Condition	*Fundella*	*Etiella*	*Maruca*	Caterpillar gone (or too small to identify)	Total
December 24	Sprayed	34	12	1	.....	47
December 31	Unsprayed	14	.....	1	10	25
December 31	Sprayed	14	2	2	13	31
January 6	Unsprayed	16	.....	.....	24	40
January 6	Sprayed	35	.....	1	12	48
January 13	Unsprayed	5	.....	.....	20	25
January 13	Sprayed	9	.....	.....	7	16
January 20	Unsprayed	1	.....	.....	6	7
January 20	Sprayed	1	.....	.....	6	7
January 28	Unsprayed	1	.....	.....	7	8
January 28	Sprayed	1	.....	.....	6	7
February 3	Unsprayed	16	.....	.....	.....	16
February 3	Sprayed	45	.....	.....	.....	45
February 3	Unsprayed	9	.....	.....	.....	9
February 10	Sprayed	18	.....	.....	37	55
February 10	Unsprayed	2	.....	.....	6	8
February 17	Sprayed	12	.....	2	30	44
February 17	Unsprayed	1	.....	1	1	3
February 24	Sprayed	16	.....	2	26	44
February 24	Unsprayed	4	.....	.....	7	11
March 2	Sprayed	1	1	.....	8	10
March 2	Unsprayed	1	.....	.....	3	4
March 9	Sprayed	13	1	1	25	40
March 9	Unsprayed	.....	.....	1	5	6
March 16	Sprayed	6	.....	4	18	28
March 16	Unsprayed	.....	.....	.....	6	6
March 23	Sprayed	3	.....	7	25	35
March 23	Unsprayed	4	1	.....	5	10
March 23	Unsprayed	2	1	.....	5	8
March 31	Sprayed	3	2	.....	17	22
March 31	Unsprayed	5	4	.....	3	12
April 6	Sprayed	7	.....	.....	21	28
April 6	Unsprayed	2	4	.....	13	19
May 5	Sprayed	.....	1	.....	7	8
May 10	.....	.....	2	.....	4	6
Total	.....	301	31	23	.....	Average 21

The absolute disappearance of *Etiella* during January and February is well shown in the above record of counts, and its scarcity during March. During the entire period, not a tenth as many *Etiella* caterpillars were noted as of *Fundella,* and *Maruca* was even less abundant. The average infestation appears considerably higher during the winter than in the spring, but it must be remembered that only culls were examined during the winter, while representative samples were available for examination from the previously observed late spring crop.

A part of one unsprayed field observed during the winter had sword beans interplanted between every five rows of lima beans, and a row of *Crotalaria incana* along one side. The *Crotalaria* did not begin to have pods until early in March, consequently no observations could be made on whether the insect passed the winter months on this (supposedly) preferred host, rather than on lima beans. No caterpillars were noted in these pods until the latter part of March, when lima beans were also beginning to be infested. On March 24th, several hundred *Crotalaria incana* pods were available for examination, of which only 2 or 3 per cent were infested by *Etiella.* On April 5th, 200 pods were examined and 15 per cent were found to be infested. In only a few cases were caterpillars present, but the indications of their former presence were unmistakable, a webbing together of the seeds, quite different from the clean injury caused by the larvae of *Utethesia ornatrix.* The *Etiella* caterpillars in *Crotalaria* have quite a different appearance from those which have fed on lima beans, having a shrunken, shriveled look, are more bluish-green in color and invariably have four longitudinal purplish-chestnut stripes running along the back. On May 12th, 444 pods were available for examination, and of these 18.5 per cent were, or had been, infested by *Etiella* caterpillars.

The sword beans also, altho planted at the same time, did not begin to come into production until several weeks after the lima beans were bearing heavily, and were as heavily infested by *Fundella* caterpillars as were the lima beans. Indeed, at no time were many sword beans attacked by either *Fundella* or *Maruca,* and, reviewing the observations now, it becomes apparent that sword beans can be of little value in attracting the moths away from the lima beans unless planted several weeks or a month in advance. Heavy infestations of these caterpillars in sword beans have been observed to occur only when the sword beans came into production at about the time the adjacent lima beans ceased to have many pods.

Out of all the hundreds of caterpillars collected, only one *Fundella*

was observed to be parasitized. It bore four globular, semi-transparent, greenish maggots attached to one side, which increased rapidly in size, becoming fully grown on the day after the drawing (See Fig. 6) was made, spinning cocoons of grey silk by the next day, and appearing as ant-like adults ten days later. These wasps were identified by Mr. A. B. Gahan as *Perisieriola* sp., probably *cellularis* (Say).

As explained in a previous paragraph, the lima beans examined during the winter of 1931–32 were only culls. From such inspections it was impossible to determine whether spraying with Bordeaux and magnesium arsenate had any effect on the pod-boring caterpillars, or not. From a casual inspection of the returns, it would seem the caterpillars were more abundant in the sprayed beans, and it appeared possible this might not be merely the appearance, but the reality. Spraying might cause the small caterpillars to burrow into the pods earlier than they otherwise do normally, thus actually de-

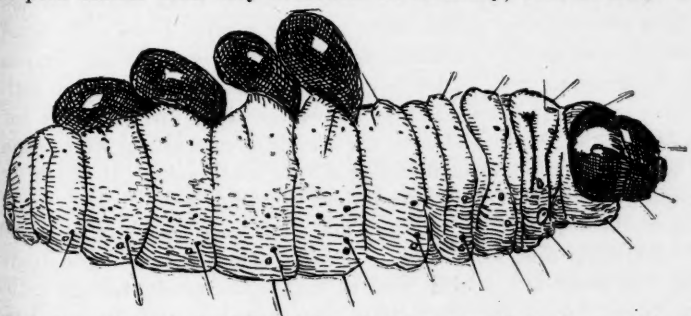

FIG. 6. Caterpillar of *Fundella cistipennis* Dyar parasitized by maggots of *Perisierola* prob. *cellularis* (Say). About fifteen times natural size. (Original).

creasing the number of deaths due to predators and other accidents befalling them while feeding outside of the bean tissue. To more definitely determine the value, or otherwise, of spraying, a specific experiment was conducted during the late spring of 1932. The plan of this experiment was as follows:

1. *Crotalaria incana* (1 row)
2. *Canavalia ensiformis* (2 rows)
3. Lima beans—untreated (3 rows)
4. Sprayed weekly with Bordeaux mixture, 2–2–50 and Magnesium Arsenate (3 rows)
5. Sprayed weekly with Bordeaux only (3 rows)
6. Check (3 rows)
7. Sprayed with poison only, 2 pounds in 50 gallons water (3 rows)

8. Check (3 rows)
9. Sprayed with Bordeaux & poison (3 rows)
10. Check (3 rows)
11. Poison only (3 rows)
12. Check (3 rows)
13. Bordeaux only (3 rows)
14. Bordeaux & poison (3 rows)
15. Untreated (3 rows)
16. *Canavalia ensiformis* (2 rows)
17. *Crotalaria incana* (1 row)
18. *Canavalia ensiformis* (3 short rows)

The seed was planted March 3, 1932, and two weeks later both kinds of beans were up, the lima beans having second and third leaves on. The *Crotalaria* shoots had not yet appeared at this time, and indeed germinated so poorly that, for the purposes of the experiment, their presence may be disregarded. It should be noted that the experiment repeats itself in the reverse order, so that Untreated 3 and 15 are comparable, being beside alternate hosts, while the other untreated rows are true checks, being between sprayed rows. The beans from all comparable treatments were combined for selecting samples for examination, and, so far as possible, these consisted of 100 marketable pods. The first samples were received on June 7th, the last on July 19th. Neither *Maruca* nor *Fundella* caterpillars were found in any beans, all caterpillars being *Etiella zinckenella.* It should be especially noted that these infestations were not in cull beans, nor in run of the field but, in selected, and apparently marketable beans. The extremely high infestation by *Etiella,* does not, however, indicate that this insect is a serious pest of lima beans grown for export to the United States, for these beans were grown during the summer, when no green beans in the pod can be shipped.

SPRAYING EXPERIMENT FOR THE CONTROL OF LIMA BEAN POD-BORER, (*ETIELLA ZINCKENELLA* TREIT.), SUMMER OF 1932, AT ISABELA, PUERTO RICO

Average	Treatments	June 7	June 15	June 22	June 29	July 8	July 19
31.....	Untreated, beside sword beans	40	20	24	41	38	26
40.5...	Untreated check.....	49	29	35	40	50	40
31.6...	Sprayed with Poison only.	37	27	32	29	39	26
36.....	Sprayed wiith Bordeaux only	44	34	27	36	47	29
48.....	Sprayed with Poison and Bordeaux	53	46	47	26	66	49
	Average Examination..	45	31	37	34	48	34

Several of the *Etiella* caterpillars collected in these examinations were parasitized by maggots similar in general appearance to the ones previously observed on the *Fundella* caterpillar, but in color a dull pinkish. They developed with similar rapidity, but spun tough

brownish cocoons, the adults emerging ten days later being quite different in appearance. These wasps were identified by Mr. C. F. W. Muesebeck as *Heterospilus etiellae* Rohwer.

The results of this experiment are not especially convincing, for the presence of *Canavalia* beside the unsprayed rows could have no possible effect on the infestation of the lima beans by *Etiella,* as sword bean is not normally a host of this caterpillar. (It should be mentioned that these sword beans were infested by *Fundella* caterpillars, even tho none occurred in the lima beans). It would, however, tend to indicate that the less one sprayed, the better, and certainly could be interpreted to mean that any expense for spraying could not be justified on the basis of its value in the control of pod-borer. The most serious criticism of the experiment, however, is that it deals entirely with the one pod-borer which does not ordinarily affect the beans grown in the winter for export. For practical purposes, the grower is concerned with *Fundella,* and with *Maruca* only as an unusual abundance may affect the possibility of meeting quarantine requirements, but with *Etiella* not at all, because it is not subject to quarantine, and also because it is so scarce in lima beans grown in the winter. Yet this experiment, conducted during the summer, concerned only *Etiella.*

To meet all of these criticisms, if possible, another experiment was planned, to be conducted during the winter, producing lima beans at the time and under the conditions affecting commercial growers. As one grower, whose statement was quoted and given considerable publicity by one of the companies marketing extracts of pyrethrum, claimed to produce lima beans that had no difficulty in being passed by the quarantine inspectors on account of infestation by pod-borers (whatever that claim might mean), pyrethrum was added to the substances tried. The only possible value for any insecticide in the control of any of these pod-borers would be in killing the eggs or the small caterpillar before it had entered the pod. To kill such minute caterpillars, a contact insecticide might be as valuable as a stomach poison, thus a trial of nicotine sulfate was added to the experiment. The Nicotrol (nicotine sulfate plus penetrol) used was contributed by the Kay Fries Chemicals Inc., and the pyrethrum, in the form of "Pyagrol", by John Powell & Co., to which firms the writer is thus indebted. The plan of the experiment is as follows:

1. *Canavalia ensiformis* (3 rows).
2. Untreated (3 rows).
3. Weekly spraying with Bordeaux mixture, 2–2–50 and Magnesium Arsenate, 2 pounds to 50 gallons of mixture (3 rows)

4. Bordeaux only (3 rows)
5. Check (3 rows)
6. Bordeaux plus "Nicotrol" (Nicotine Sulfate and "Penetrol") 1 part to 200 of liquid (3 rows)
7. "Pyagrol" (Pyrethrum plus "Penetrol"), 1 part to 200 of water (3 rows)
8. "Pyagrol" (3 rows).
9. Bordeaux plus "Nicotrol" (3 rows).
10. Check (3 rows)
11. Bordeaux only (3 rows)
12. Bordeaux & Magnesium Arsenate (3 rows)
13. Untreated (3 rows)
14. *Canavalia ensiformis* (3 rows)

Seed was planted on November 18, 1932, and weekly spraying commenced as soon as the first bloom appeared, about two months later. The first samples, 100 pods, unselected, from each series of rows, were received on February 20th, 1933, and as the experiment was being conducted in reversed duplication, were combined to form samples of 200 pods from each treatment. The sixth lot of samples, received March 27, consisted of the total production for that week, but was insufficient to make up the total number of the other samples. Production practically ceased for a time thereafter, but the seventh shipment, April 20th, was of the required number. The experiment was conducted in Isabela, but examinations were made at Río Piedras on the day after picking.

SPRAYING EXPERIMENT IN THE ATTEMPTED CONTROL OF THE LIMA BEAN POD-BORER CATERPILLARS: *FUNDELLA CISTIPENNIS* DYAR. *ETIELLA ZINCKENELLA* TREIT. *MARUCA TESTULALIS* GEYER, CONDUCTED AT ISABELA, PUERTO RICO, WINTER AND SPRING OF 1933

Dates	Number of Caterpillars per 100 Pods (Samples of 200)									
	Feb. 20	Feb. 27	March 6	March 13	March 20	March 27	April 21	April 29	May 10	May 20
Treatments:										
Beside *Canavalia*	2.5	6.0	4.0	2.5	6.0	7.1	3.5	1.5	9.5	17.5
Bordeaux & Mg. Arsenate	5.0	4.0	2.5	4.5	4.0	5.0	1.0	6.0	5.5	10.0
Bordeaux only	3.0	5.0	2.0	4.0	4.0	6.3	1.5	3.5	5.0	11.0
Check	3.5	10.0	5.0	4.0	5.0	3.7	4.0	4.5	4.5	14.0
Bordeaux & Nicotrol	2.5	4.0	6.0	5.0	3.5	1.4	.5	2.5	3.5	8.0
Pyrethrum	1.5	1.5	5.5	3.5	4.5	3.2	1.5	3.5	5.5	6.5
Average	3.0	5.1	4.1	4.	4.5	4.5	2.0	3.6	5.6	11.3
Total Caterpillars Identified each examination:										
Fundella	19	23	20	7	13	5	3	0	2	6
Etiella	0	0	1	3	2	2	1	8	16	60
Maruca	1	4	0	1	0	0	1	1	0	0

The first two examinations appeared to indicate that the caterpillars were being controlled in the rows sprayed with pyrethrum.

Most unfortunately, later pickings failed to show any advantage from the use of this extract, and indeed sprays with other substances gave even lower infestations during some later weeks. Of course it is possible that the use of pyrethrum at greater strengths, or oftener, might give complete control, but it is doubtful if such treatments would be commercially practical. Thus the experimental evidence, to date, indicates no method of control for the lima bean pod-borer caterpillars.

The final experiment, valueless from the control standpoint, is most interesting otherwise in indicating just when *Fundella* caterpillars cease to be abundant in the spring and their place is taken by much greater numbers of *Etiella*, fully a month after shipment to the States has been discontinued on account of quarantine restrictions.

THE LARVAL PERIOD OF DIAPREPES ABBREVIATUS L.

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In proportion to its economic status, the weevil root borer of the West Indies, *Diaprepes abbreviatus* L., (=*spengleri* L.) has received surprisingly little careful study. Most of our information regarding the insect has been confined to the period of its aerial existence; what happens to the subterranean forms is for the most part inferred rather than known. The exclusively aerial adults, large weevils striped with black and white or bright colors, feed on the tender leaves of many kinds of trees and plants. Clusters of from ten or a dozen to several hundred oval eggs are laid between two older and tougher leaves glued together, hatching of the grubs occurring in six to ten days. The grubs do not burrow thru the leaf, all such holes being made by the wasp parasites, but wiggle out from between the leaves, dropping at once to the ground, into which they burrow. From the beginning, they feed only on live vegetable tissue, so far as known attacking all kinds of plant roots with impartiality. After a larval period presumed to occupy most of a year, pupation occurs in a cell at some depth in the earth. The pupal period is short, about fifteen days according to all observers. Some time may be spent as adult in the pupal cell, but once the adults have emerged from the earth, they never again return to it.

Injury to economic plants is caused by both larva and adult, citrus trees and sugar-cane being most often attacked. In Barbados, the insect is practically restricted in all host relationships to sugar cane: the adults feeding on the leaves, the females laying eggs between the split tips of the leaves, the young grubs feeding on the roots, the older grubs burrowing into the root-stalk, and the pupa often being formed in a cavity in the cane stool. Elsewhere the adults feed on the leaves of many wild and a few economically valuable plants, and the grubs are apparently unrestricted in their choice of roots on which to feed.

The range of the insect is from Barbados to eastern Hispanioia, and over this range the adults differ so greatly in color markings and general appearance that numerous varieties and species have been described, all of which, we are assured by the systematists, belong to but a single species. The variation in the size, color and habits

of the adults may appear in the grubs as a variation in behavior and length of the larval periods, for regarding the latter, no observers agree. Over thirty years ago, that enthusiastic amateur entomologist, the Rev. N. B. Watson, in Barbados reared a few individuals from egg to adult and determined the larval period as being from 300 to 312 days. A dozen years later, Wm. Nowell in Barbados found 261 days, 326 days and 334 days as the length of time before pupation for rearing immatures grubs of small size. Judging by the few completed rearing records, the larval period in Puerto Rico may be considerably shorter. Three grubs only, out of the hundreds used in the experiments that have been conducted here in the past two years, have been successfully reared from the just hatched larva to pupa, the larval periods for these three grubs being 202 days, 238 days and 268 days respectively. (See Table, p. 259.)

All of the grubs have been carefully observed as to molting; the one attaining the pupal period in 202 days pupating from the 10th larval instar, the one pupating in 238 days having attained complete larval development in only six instars, while the one requiring 268 days to become a pupa changed from the ninth instar. From such a small number of individuals, no generalization of value can be made, and indeed one can not be sure that these individuals pupating in such a short period are not exceptional rather than normal individuals. Other grubs have molted to the 16th instar, in one case after only 220 days, while other individuals have lived over a year as larvae. Not one of these other grubs, however, has succeeded in evading the varied perils inherent in the more or less unnatural conditions attendant on artificial rearing and constant observation, and most of them have died before pupation. Unquestionably, all of these grubs were sound and healthy in their earlier instars, while they were growing rapidly and making constant gains in size and weight, but having attained maximum weight, they entered a period of inactivity and failure to eat, a cul-de-sac from which the only escape was not pupation, but death. A few of these grubs are still alive, but the stimulus which will cause them to continue their transformation is not yet determined. Admittedly the present paper is incomplete and essentially preliminary. While the completed rearing records may be considered as finished and final, all the general statements made are tentative, and subject to change as additional results accumulate.

The first year's rearing was conducted at Isabela, the second at Río Piedras, and despite the fact that the same type of container, the same cabinet for holding the rearing boxes, the same food and in

LARVAL PERIODS OF *DIAPREPES ABBREVIATUS* L., SELECTED INDIVIDUAL RECORDS AND AVERAGES OF ALL RECORDS: DAYS AFTER HATCHING TO BEGINNING OF INSTAR

	Completed normally			Incomplete: died before pupation												Averages of All Records	
Reared at	Río Piedras	Isabela		Río Piedras						Isabela						Río Piedras	Isabela
Instars Date hatched	Sept. 10	July 5	May 5	Dec. 24	Oct. 5	Sept. 1	Aug. 5	Oct. 5	Aug. 5	Jan. 19	Nov. 17	Oct. 1	May 5	June 22			
2nd	12	31	27	....	.....	12	10	10	17	31	23	8	11	.....	.....	.....	28 34 grubs)
3d	21	38	33	23	19	21	20	20	29	59	41	18	32	32	89	21 (77 grubs)..	46 (34 grubs)
4th	25	51	42	34	24	30	29	29	44	78	77	38	64	52	135	29 (82 grubs)..	66 (38 grubs)
5th	33	145	57	39	33	35	41	41	57	103	94	106	92	101	163	37 (84 grubs)..	100 (37 grubs)
6th	42	172	130	46	42	53	51	52	66	114	103	156	200	134	251	47 (82 grubs)..	146 (34 grubs)
7th	82	.....	153	53	49	62	63	73	110	124	132	185	219	163	305	62 (82 grubs)..	184 (30 grubs)
8th	115	.....	211	59	71	72	83	92	136	138	143	210	273	256	339	88 (88 grubs)..	221 (21 grubs)
9th	128	.....	227	81	101	86	103	114	166	167	183	280	316	305	.....	117 (80 grubs).	262 (13 grubs)
10th	173	.....	.....	107	124	102	125	134	196	192	233	308	339	340	.....	148 (68 grubs).	300 (6 grubs)
11th	.....	.....	.....	130	141	123	148	145	228	.....	.....	355	.....	361	.....	170 (52 grubs).	.....
12th	.....	.....	.....	161	159	142	166	152	246	.....	.....	.....	.....	.....	.....	195 (38 grubs).	.....
13th	.....	.....	.....	.....	202	156	.....	156	263	.....	.....	.....	.....	.....	.....	218 (18 grubs).	.....
14th	.....	.....	.....	.....	217	177	.....	171	285	.....	.....	.....	.....	.....	.....	.....	.....
15th	.....	.....	.....	.....	227	191	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
16th	.....	.....	.....	.....	239	220	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
				Minimum to 8th instar	(Fed corn only)			(Fed beans only)	Maximum to 8th instar for Río Piedras	Minimum to 8th instar for Isabela					Maximum to 8th instar		
Pupa	202	238	268	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Adult	.....	.....	289	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....

many cases the same soil were used in both localities, the grubs attained full size in a much shorter time at Río Piedras. The factors of difference, so far as known, are three. The grubs were examined every week at Isabela, but at Río Piedras they could be watched more carefully, examinations being made usually three times a week. The water used to moisten the soil at Isabela was taken from the irrigation ditch; that at Río Piedras was city water which often was heavily chlorinated. The mean minimum air temperatures at Río Piedras averaged two or three degrees lower than at Isabela during the winter only, otherwise they were practically the same. How this affected the soil temperatures is problematical. The speeding up to growth in Río Piedras applies also to the total larval period, for the minimum of 202 days was obtained here, the other two records being of Isabela grubs. It was not a characteristic of the grubs themselves, for some of the grubs reared at Río Piedras were from egg-clusters collected at Isabela, others were from Florida (between Arecibo and Barceloneta), only the minority being obtained locally.

Various sizes of tin salve boxes have been used as containers, but finally the two ounce size was adopted for all work as being the most desirable. The soil used was that most readily available outside the laboratory door, the only selection being to eliminate large sticks, stones or other debris, the earth particles carried up out of their tunnels by ants often being selected. At first, soil brought from Isabela was used at Río Piedras, until a considerable expansion of the experiment required additional amounts, which were picked up locally. In many cases, previously discarded soil which had been thoroly dried or baked was used in preference to obtaining fresh soil from the garden. Moisture was added by means of a medicine dropper, attempting to keep the soil reasonably moist at all times, and only excessively moist when seeds were to be sprouted.

As food for the grubs, corn only was used at first; later, fresh lima beans were added. As the lima beans were subject to rot, sword beans were substituted, the usual combination placed in one box with a grub being two grains of corn and one bean. So far as could be determined, the grubs fed on the corn or beans with strict impartiality, and apparently throve equally well on either. To determine the effect of food on rapidity of growth, half the grubs from one egg-cluster hatching on October 5th were placed in cans supplied only with corn, the others in cans supplied only with sword beans.

In the first instar, the mortality was greater among the grubs supplied only with corn, so that only five survived, as compared with twice as many which lived to eat beans. Yet these five grubs eating corn averaged from two to fourteen days less time in reaching each instar up to the ninth. By the tenth instar, however, when all the grubs had ceased feeding, those which had previously eaten only sword beans molted nine days ahead of those previously eating corn. In the molt to the 11th instar, the corn-eating grubs were one day ahead, in the molt to the 12th, nine days ahead, yet in the molt of the 13th, their respective positions were again reversed, those which had eaten corn being three days ahead (214 days vs. 217 days). Such slight differences may be considered as due to individual variation, and indicate that no significance is to be assigned to food.

Extreme seasonal variation in abundance of adults has repeatedly been noted, yet adults are present at all times, and egg-clusters have been collected during every month of the year at both Isabela and Río Piedras. No special effort has been made to rear grubs from the eggs of every month, and indeed only minor differences are to be noted in rapidity of growth of the grubs during the warmest and the coldest months. It is possible that the grubs grow most rapidly during cooler (tropical) weather, and the majority of the rearings would appear to indicate this, yet so many individual exceptions are to be noted that it is by no means certain. Some grubs hatching from egg-clusters laid in December have attained maximum size in two months, or a little longer, but other individuals from the same cluster required as long, or longer, than grubs hatching out early in August. Individual variation is much greater than seasonal variation, some of the grubs from one large egg-cluster hatching in December requiring more than twice as long to make the same gains in size and weight as others from the same cluster. Some grubs are exceptionally slow in the earlier instars, others in the later growth instars, all from the same egg-cluster, and reared under as nearly as possible the same conditions. Inividual variation in rapidity of growth does not follow the normal curve, for the majority of grubs are close together, making rapid gains in size and weight with none greatly in advance, but the minority strings out almost interminably behind Some of the delayed minority may later catch up, or almost catch up with those which have made the most rapid growth at first, and others are permanently greatly delayed, yet they seem as healthy and normal as any others. (See Plate XX.)

No explanation can be given of the failure of some grubs to eat and grow as fast as others from the same cluster, more especially

when all were in the same container during the earlier instars. An abundance of food was available at all times, and the grubs were so active that they could hardly have failed to come into contact with it. Molting, however, at least during the earlier instars, is to some extent dependent on soil moisture, being inhibited when the soil is dry, but ensuing within a few minutes after a sudden access of water. Wm. Nowell is of the opinion (**2**) that pupation also normally follows spring rains after the comparatively dry winter weather of Barbados, but no pertinent observations on this point have been made in Puerto Rico.

The larval period of *Diaprepes* grubs falls into two parts: (1) a period of constant and rapid growth, extending from hatching to about the beginning of the eighth instar, during which time the head-size of each instar is noticeably different so that each instar may at once be recognized by examining the grub itself, and (2) a period of equal or even greater length when the size and weight of the grub remains constant, or tends to decrease, extending from the eighth instar, or earlier, to pupation, during which period the number of molts can be determined only by keeping track of the molted skins. In the first period, the grub is feeding most of the time, in the second it eats little or not at all. Some individual grubs in the second period molt almost as frequently as previously, but most of the grubs at much greater and very irregular intervals. Individual variation is even more marked than in the first period, and the problem of maintaining the grubs alive and healthy becomes increasingly difficult. So few of the grubs have successfully passed thru this period of inactivity under artificial rearing conditions that most of the data accumulated concerning it is admittedly false. It seems very improbable that under normal conditions it usually ends in the death of the grub. All the activities of the insect occupy less than half a year, but this long, indefinite and indeterminate waiting period of the larva before pupation stretches out the life-cycle so that it will fit into the seasonal pattern of a year. It suggests that the insect should be better adapted to a climate inducing a long period of hibernation or aestivation, altho the period does not, or may not, actually coincide with any extended period of temperature difference.

Regarding the first period of activity and rapid growth we can be much more certain that the data accumulated are reasonably correct. Grubs in both periods have been weighed during all instars, not the same individuals, but ten or a dozen individuals in each instar, and, with some minor adjustment of these averages, we can be reasonably certain that the majority of the grubs in this first period make

steady and constant gains in weight. To be sure, this steady gain is interrupted at every molt, for every molt results in a small temporary loss, but if one considers the gain from about the middle of one instar to the middle of the four succeeding instars, the resulting curve will be a straight line. Starting with the newly hatched larva weighing .000125 gr. each, in each of the succeeding five intervals of ten days, at Río Piedras, (from hatching to the middle of the first instar, from the middle of the first instar to the middle of the second, from the middle of the second to the middle of the third, etc., each one of which is approximately a ten day interval at Río Piedras) the increase in live weight is *four* times: to .0005 gr., to to .002 gr., to .008 gr., to .032 gr., to .128 gr. by the middle of the fifth instar. This is the period of most rapid growth.

Following it is a transition period of less rapid growth. From the middle of the fifth to the middle of the sixth instar,, the interval is no longer, but the increase in weight is only *three* times, to .384 gr. From the middle of the sixth to the middle of the seventh instar, the interval is one-half longer, to fifteen days, and the increase in weight is only one and one-quarter times, to .48 gr. Individual grubs may weigh considerably more than this in the 7th and later instars, the maximum observed for any grub being .74 gr. for one individual in the 9th instar. The average weight, however, of those in any of the later instars is .5 gr. or a little less. Most grubs attain their maximum weight in the eighth instar. For most grubs, and for the average of all grubs, molting to the eighth instar marks the end of the period of growth and the beginning of the period of inactivity preceding pupation. At Isabela, the period interval between the middle of succeeding earlier molts, instead of being ten days as at Río Piedras, was fifteen days, and in addition to being one-half longer, began to lengthen earlier, to thirty days between the middle of the fourth instar to the middle of the fifth, and to forty days for the succeeding instars.

Up to the middle of the fifth instar, the grubs are of insignificant size so far as the damage they are capable of causing to the roots of plants is concerned, but the slowing down of their rate of growth coincides with the period when they are of sufficient size so that the result of their feeding activities is a very noticeable loss to the farmer. That they should grow so rapidly in the first two months results in no noticeable and obvious injury to well established plants, but their feeding in the next month results in the maximum injury they are capable of causing. This point is of the greatest practical im-

portance to farmers, especially those who are growing vegetables between young citrus trees for instance. The appearance of large numbers of adult beetles feeding on the tender leaves of their citrus trees is not only a direct loss of foliage but indicates that in from two to three months later the roots of these citrus trees and the roots of vegetables growing between them will suffer the maximum injury from the grubs hatching from the eggs laid by the female beetles. After this period of greatest injury to the roots, fully grown grubs may be present in the soil and around the roots for several months, but the injury they cause is all past. They are no longer actively feeding. Their growth curve has dropped to zero.

Two kinds of curves may be drawn to represent what has happened. The one representing relative growth is at a high level for the first two months, drops slowly at first but later with increasing rapidity in the third month, and by the fourth month is below zero, continuing here until pupation. The curve showing absolute weights is scarcely apparent in the first month, rises rapidly in the second month, makes enormous gains in the third month, a slight gain in the fourth month (but still at a high level), and drops only a little below this high in the succeeding months to pupation. Except in the latter months, it parallels the curve of injury to the farmer's crops, insignificant in the first two months, attaining a maximum in the third and fourth months, but again dropping to insignificant proportions later, when the grub has ceased to feed and is merely waiting for pupation.

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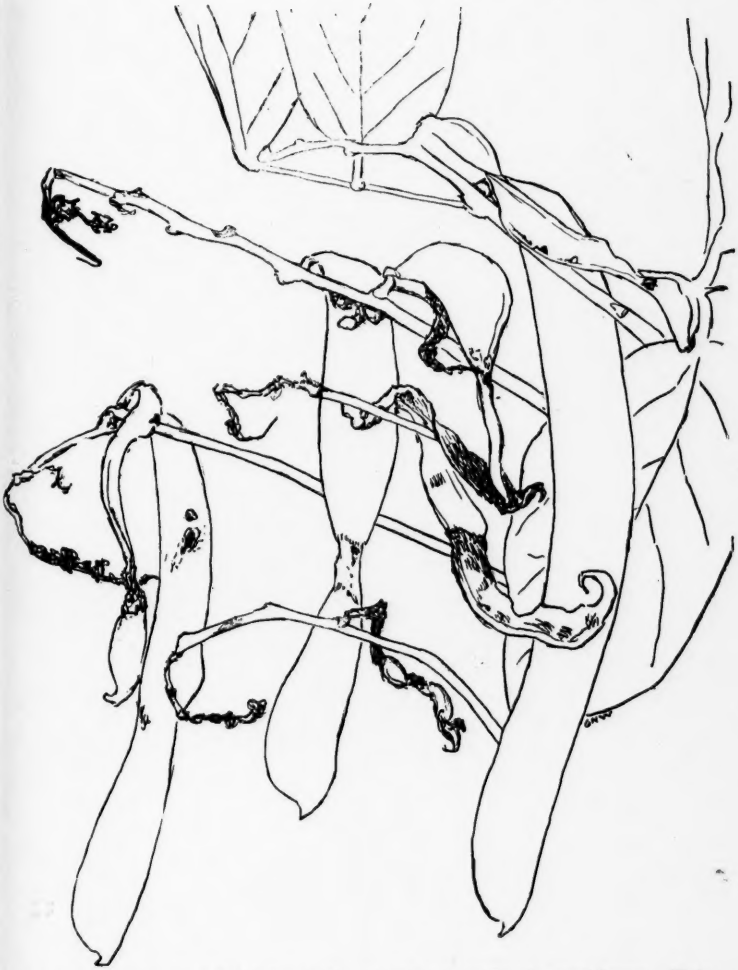
PLATE XIX.



Injury of caterpillars of *Fundella cistipennis* Dyar to pods of sword beans. Note only one uninjured pod of all those shown, the smaller pods being withered and about to drop, the larger ones being malformed by infestation at a later stage of growth. (Original).

5th.

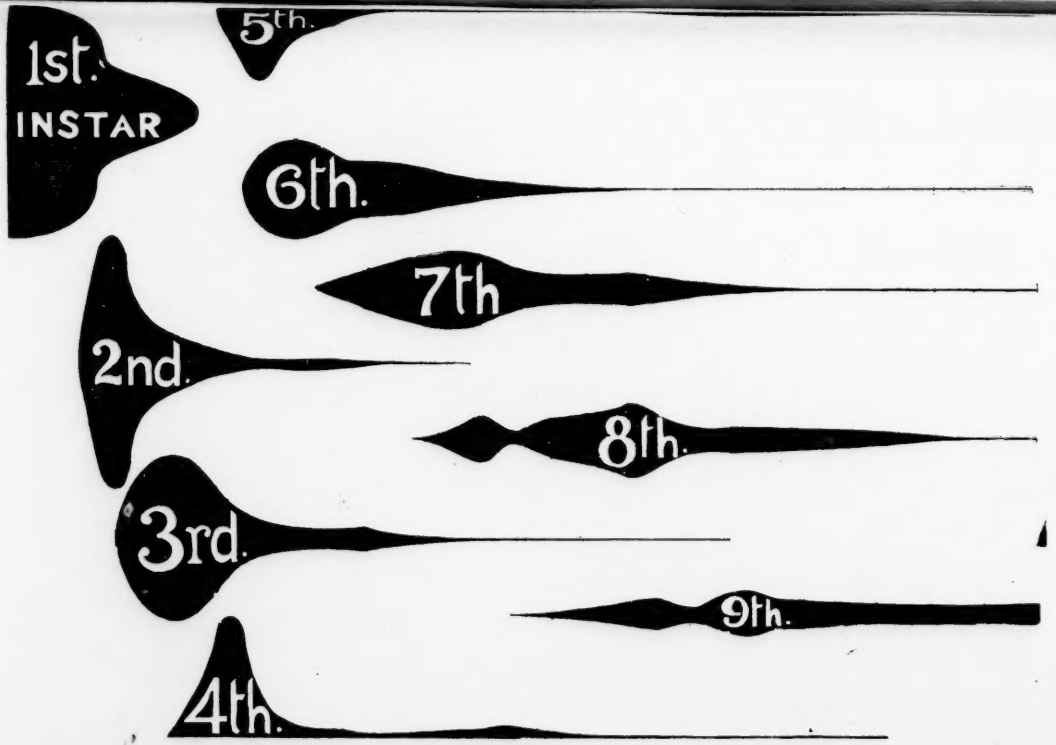


PLATE XX.

Length of Larval Instars of *Diaprepes abbreviatus* L. at Río Piedras: total horizontal distance represents two hundred days, vertical distance indicates number of grubs. (Original. Drawn by Fernando Chardón.)

THE CHANGED STATUS OF SOME INSECT PESTS IN PUERTO RICO

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A few of the insect pests of economic crops in Puerto Rico show little or no change in their status over a period extending as far back as any entomological observations are recorded. For instance, the purple scale of citrus trees, *Lepidosaphes beckii* Newman, has been and still is THE scale for which growers spray or maintain windbreaks, obtaining commercial control thereby, but never reducing its numbers below a certain minimum from which it will promptly recover under favorable conditions. The mole-cricket, or *changa*, *Scapteriscus vicinus* Scudder, is generally quite as much of a pest now as it has ever been in the past, the decrease in its numbers reported by some farmers due to toads being more than balanced by increased damage reported in other districts, due either to a more intensive type of agriculture or to an actual increase in its numbers. In the regions where the use of the standard Paris green-flour mixture for poisoning the *changa* is still in common use, it probably is now less abundant than formerly, but where farmers have reverted to merely protecting young plants against its attack by wrapping them in *mamey* leaves when transplanted, it is subject to no control except natural factors. To be sure, it is eaten by the imported giant toad, *Bufo marinus*, but apparently only in limited areas has a noticeable reduction in its numbers resulted.

Of the pests which have appeared here in recent years, the latest arrival is the cottony cushion scale, *Icerya purchasi* Maskell. A detailed account of this insect is given elsewhere in this number of the Journal (1), noting its peak of abundance in the late spring of 1932, and the role of parasites, predators, entomogenous fungi and hurricanes in its control. *Coccus viridis* Green, the soft green scale of citrus and coffee, was first noted in 1925, and became noticeably destructive in the coffee groves denuded of shade by the hurricane of San Felipe in 1928. Its present status largely depends on local humidity, for its numbers are greatly reduced by at least two kinds of entomogenous fungi attacking it, which thrive during wet weather. Thus it is rarely injurious on large citrus trees, or in coffee groves well protected by shade, but during dry weather may be seriously

injurious on young citrus trees. In 1921, two pests appeared almost simultaneously in Puerto Rico, the pink bollworm of cotton, *Pectinophora gossypiella* Saunders, and the corm borer of plantains and bananas, *Cosmopolites sordidus* Germar, both of which now occur practically everywhere that appropriate host plants are present. The latter pest apparently has no natural enemies, and comparatively few growers practise, or even know, the practical methods of control by which its numbers may be reduced to a minimum. The rapidity with which it has spread, and the abundance in which it is now present, does not indicate, however, that other insects with similar habits will be similarly successful. The sweet potato weevil, *Cylas formicarius* F., altho a most serious pest in the poor, hilly lands of the interior, is of comparatively little importance on the richer loams or the sandy lands of the coast, where the host grows to much better advantage, matures more rapidly, and is further protected from attack by the absence of cracks in the soil thru which the insect can reach the tubers. Even less successful in extending its range is another weevil of sweet potatoes, the scarabee, *Euscepes batatae* Waterhouse, which is still confined to limited areas where the first records of its presence in Puerto Rico were made. Its limited distribution is paralleled in the case of the papaya fruit fly, *Toxotrypana curvicauda* Gerstaecker, which is comparatively rare even in the restricted region where it is present.

For the 29-year period, 1899 to 1928, no generally and seriously destructive hurricanes have happened to strike Puerto Rico. One consequence of this lengthy immunity from hurricanes was that the coffee shade tree ant, the "hormiguilla", *Myrmelachista ambigua ramulorum* Wheeler, became constantly more abundant, for old infested shade trees in the coffee groves became so large that they could not be removed without injury to the coffee trees underneath. The hurricane of San Felipe brought down these old guaba and guamá trees, thus immediately eliminating the great bulk of the hormiguilla population of the grove. Only gradually, over a period of several years, as the freshly planted shade trees again attain considerable size, will the numbers of the hormiguilla again begin to increase.

The hurricane incidentally increased the number of the more common cotton insect pests in the few years immediately following, for the impoverished coffee growers in many cases attempted to grow cotton for a cash crop. Waves of infestation by the leaf caterpillar, *Alabama argillacea* Hübner, swept over these plantings, and infestations of the pink bollworm were built up, culminating in almost

total infestation of the end of the crop for 1931–32. From this high peak, cotton insects rapidly receded, due to the discouraged coffee planters abandoning the crop, and even cotton farmers ceasing to plant on account of low prices and the withdrawal of the sole buyer. The hurricane of San Ciprián in the fall of 1932 destroyed the fruiting portions of the maga trees, thus eliminating the only important alternate host of the pink bollworm along the north coast. Where volunteer cotton plants still exist, the pink bollworm continues to persist, but in the main cotton region, around Isabela, where volunteer cotton plants had been eliminated years ago, the destruction of the fruiting portions of the maga trees and the absence of commercial cotton fields have, temporarily at least, entirely eliminated this pest from the region.

Replacing the old standard varieties of sugar-cane grown in Puerto Rico with BH (10)12 and SC 12(4) has considerably increased tonnage and sugar content, but it has also affected the common caterpillar, *Diatraea saccharalis* F., which bores in the stalks, most advantageously to the insect. The new canes are larger and softer and sweeter than the old, and they appear to furnish a more desirable environment for the insect. Thus the numbers of this, the most serious pest of sugar-cane, have been on the increase, despite the fact that the non-burning of trash has been ever more widely adopted. Favoring its parasites by non-burning of trash can not begin to neutralize the effect of a more favorable environment furnished by the new varieties of cane. Thus, altho the net result of the change of varieties has been to increase production, this is despite the greater losses at present being caused by *Diatraea*. The stalk borer is not the only insect affected by the change in varieties. What was previously only a minor pest of sugar cane, the yellow aphid, *Sipha flava* Forbes, has also thereby been provided with a greatly superior host, from its standpoint. Because of some undetermined peculiarity of Uba and the Java canes, it often becomes enormously abundant on these varieties, and such mass infestations spread to adjoining fields of B H (10) 12 and S C 12 (4), causing much greater and more extensive losses from this pest than were ever known on the standard varieties.

The major and most obvious change which has occurred recently is in the status of white grubs, the numbers of which have decreased so greatly that only rarely and sporadically do they cause serious damage. Fifteen or twenty years ago the damage caused by white grubs had attained its maximum, and at that time they were the

most serious pests of practically every crop grown on the island, such damage being most severe in the irrigated cane lands of the south coast. It was a common occurrence to have nearly mature cane so completely denuded of roots that the stalks could be pulled up with ease, or, in extreme cases, they would fall to the ground at a touch. White grubs were distinctly the main entomological problem in Puerto Rico, and a consideration of methods of control occupied the attention not only of entomologists but of cane growers and field men generally. As none of the methods of chemical control or parasite introduction proposed by the entomologists proved to be economically feasible, or likely to produce results within a reasonable time, the field men were forced to adopt such obvious methods as hand picking of the grubs after the plow and of the adult beetles from young cane, expensive, essentially temporary and only partially effective as such methods admittedly were.

Today it is difficult to realize the seriousness of the white grub menace, for the grubs are no longer present. Hand collection of the grubs and beetles has been almost universally abandoned because it is no longer necessary, and is now so exceptionally used in rare instances only as to indicate how greatly the status of the white grub has changed. To be sure, cultivation practises have been improved, plowing is deeper, the land is better fitted for plant cane, and even the kind of cane itself is changed, being more vigorous varieties with stronger and more rapidly developing root systems, but these are only minor factors to account for the practical disappearance of the native white grubs generally from the cultivated fields of Puerto Rico.

The major factor in a changed environment for white grubs is the introduction and wide-spread dispersal of the giant toad, *Bufo marinus* L. Nearly a third of the food of this animal in cane fields consists of May beetles, the adults of the white grubs. If the toads were comparatively scarce, as are the native toads for instance, their influence might be negligible, but as a matter of fact they are at the present time very numerous, not only along the coast, but also far up into the hillier districts of the interior. On account of their individual size, their abundance, and their preference for May beetles as food, they have rapidly changed the status of white grubs in the cane fields of the south coast, and in the agricultural regions of the island generally, from that of a major pest to one of comparatively minor importance. No prediction can be ventured as to how long this condition will last: whether it is merely a temporary low for white grubs, or whether it may possibly be more or less permanent,

a permanent adjustment to the new factor. When the oscillations of the balance of nature are upset by the introduction of a new major factor, usually the numbers of the host are so greatly reduced by the parasite or predator that the parasite or predator shortly must perish in large numbers on account of lack of food. In the case of such an omnivorous predator as the toad, however, not limited in its choice of food to any particular kind of insect, the prospect of many individuals starving to death on account of lack of food may be indefinitely postponed, even if May beetles become much scarcer than they are at present. A considerable number of other Scarabaeid beetles, of little or no direct economic importance, but almost the equivalent individually of the May beetles in size, are very abundant at times, and these constitute even now a seventh of the food of toads in cane fields, and may come to be a more important factor if the number of May beetles shows a decrease below its present previously unprecedented low.

Combining all the Scarabaeid beetle items in the toad's food (amounting to nearly half of all food eaten) and adding to this an additional quarter consisting of millipedes, one can readily see how little is to be expected from the toad in affecting other insects, for the present at least, and so long as a sufficient supply of May beetles and millipedes is available. Eventually the changa may be much more generally eaten, but it was found to be only one-fortieth of the food in 1930–31 (**2**). Is it surprising that the changa continues to be a major pest, and that white grubs have almost disappeared?

At times, and locally, even exceeding white grubs in numbers and in the damage it causes to cane is the weevil root-borer grub, *Diaprepes abbreviatus* L., the adult of which is an exclusively aerial, leaf-feeding, short-beaked weevil. The adult beetles rarely feed on cane leaves, but are a serious pest of citrus trees, especially of young trees which have just been set out in the grove, and they also feed on the tender leaves of numerous other trees of little or no economic value. So far as can be judged, the numbers of this pest now average little less than at any time in the past. Altho the exclusively aerial habits of the adults might appear to render them largely immune from being eaten by toads, the weevils in fact form the third largest single item in its food, an eighth of the total. Eventually this may be considerably increased if other large insects, such as the Scarabaeid beetles, become less numerous, and seems not only possible but decidedly probable. One other important factor tending to limit the number of *Diaprepes* is an egg parasite, *Tetrastichus haitiensis* Gahan. Not until 1929 was this common insect discovered in Puerto

Rico, but its so recent discovery can hardly mean that it was not previously present. The parasite is so common that it ordinarily destroys from 50 to 95 per cent of all egg-clusters laid between the leaves of citrus or wild fig, but it can not penetrate to the eggs when they are laid between the split tips of cane leaves, and these only were collected and examined by the earlier investigators. Thus the egg parasite is not a new controlling factor, like the introduced toad, and is static, not likely to greatly increase in importance in the near future.

If any considerable decrease in the number of *Diaprepes* has already occurred (altho at present imperceptible to entomologists or farmers generally), or does occur within the next few years, it presumably will not be due to egg-parasites, but to a scarcity of other food forcing the imported toad to catch and eat larger numbers of these leaf weevils.

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